New Scientist

WEEKLY 3 August 2019

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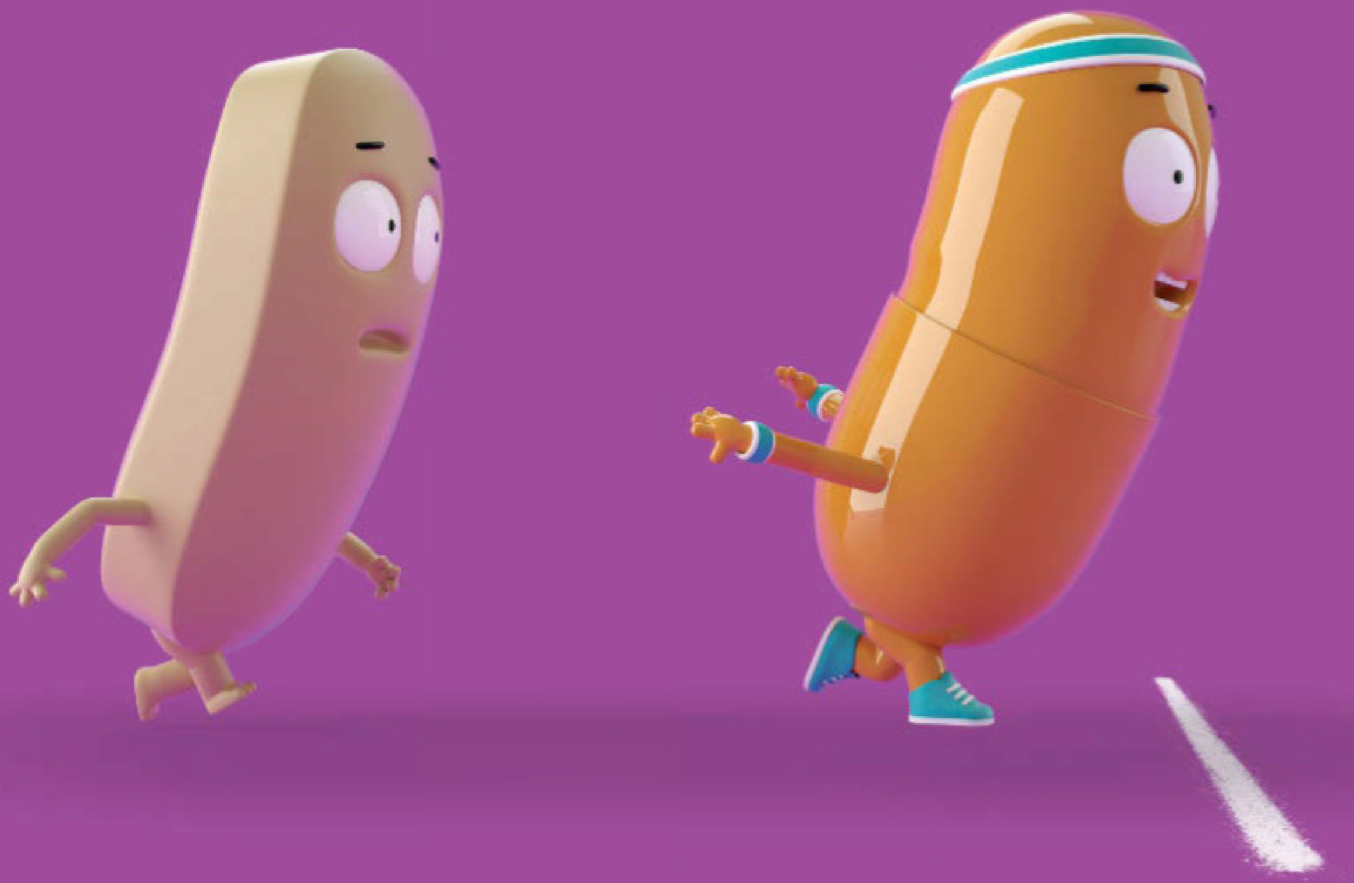

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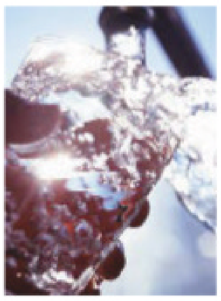
Water, water everywhere...

New thinking is required to avoid conflict over the world's drinking supplies

"IS THIS the beginning of the water wars?" It is a question *New Scientist* asked back in 2008, as drought forced the authorities in Barcelona to consider importing drinking water from over the border in France.

It seems a little hyperbolic now. But a decade ago, it was a common theme that the next big conflict would be over water. Today such talk has all but disappeared from public debate, subsumed into wider concerns about climate change.

The two issues are, of course, inseparable. Global warming is altering weather patterns, prolonging periods of drought in some places, while making rainfall more intense and unpredictable in others. To see the future, look to Australia: while New South Wales experiences a prolonged drought, in February parts of northern Queensland had monsoon conditions with 1.4 metres of rain in just two weeks.



PETER CADE/GETTY

Global water demand is projected to rise by 20 to 30 per cent by 2050

It is a slippery slope from water stress to water conflict. More than 4 billion people – half of humanity – experience severe water scarcity for at least one month a year. The Water Conflict Chronology, published by the Pacific Institute in Oakland, California, lists 279 instances of conflict over water since 2010.

With global water demand projected to rise by 20 to 30 per cent by 2050, new flashpoints will emerge. A paper last year by researchers at the European Commission's Joint Research Centre identified five major regions of concern: the river systems of the Nile, Ganges-Brahmaputra, Indus, Tigris-Euphrates and Colorado.

Ensuring everyone has access to clean, safe and reliable drinking water is in all our interests, as is carefully managing this most precious of resources, wherever we live in the world. Big, forward-thinking solutions such as technology that can draw drinking water from the air can be part of the solution (see page 38). Researcher Omar Baghi's drive came from personal experience of water shortage as a child.

We must do all we can to ensure future generations don't go to war over water. ▮

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Brainy chip Sophisticated chip can handle two types of algorithm **p12**

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JOE GIDDENS/PA WIRE/PA IMAGES

Record-breaking heat

Met Office confirms the highest temperature ever recorded in the UK, following an extreme European heatwave. **Michael Le Page** reports

AS THE world warms, more all-time national heat records have been set. The 38.7°C recorded in Cambridge (pictured) on 25 July during the recent European heatwave has now been confirmed as the highest temperature ever recorded in the UK.

The UK Met Office took several days to confirm the record, first checking the instrument located in Cambridge University Botanic Garden that recorded it.

The 25 July also saw all-time national records set in Germany (42.6°C), Belgium (41.8°C), Luxembourg (40.8°C) and the Netherlands (40.7°C). Many more places across Europe recorded their highest ever temperatures.

The heatwave was caused by a weather pattern that drew hot air from Africa northwards across a broad swathe of Europe. Such patterns occur from time to time, but because parts of North Africa are now 2°C hotter on average than in pre-industrial times, the plume of hot air was much hotter than it would have been without global warming.

"When the weather patterns, like we saw last week, bring air from this region to our shores, it can bring a stronger signal of climate change with it too," said Peter Stott at the Met Office in a statement.

The heatwave disrupted travel in the UK as overhead wires on railways sagged and tracks buckled in the heat. Severe thunderstorms triggered by the heat and humidity also caused flight delays.

The July heatwave in Europe came just a few weeks after a June heatwave set records. Many other parts of the world have also had record heat this year.

So far this year, 11 countries have recorded their hottest ever temperatures, according to weather records compiler Maximiliano Herrera. None have recorded their coldest ever temperatures.

The latest heat records aren't likely to last long. The world has warmed around 1°C since pre-industrial times and is on track to warm 3 or 4°C by 2100. As warming continues, heatwaves will become ever more extreme. ▮

Carbon emissions

China on track for climate goals

CHINA'S emissions may peak at 13 to 16 gigatonnes of CO_2 between 2021 and 2025 – years earlier than its target of "around 2030" in the Paris climate agreement (*Nature Sustainability*, doi.org/c8w5).

This reflects the nation's efforts to mitigate climate change as part of an economy that focuses on high quality, instead of high speed, says Haikun Wang at Nanjing University, China.

China accounts for a quarter of all humanity's emissions, making it a crucial part of efforts to meet the Paris goal of limiting temperature rises to 2°C. ▮ **Adam Vaughan**

Animal intelligence

World's smartest dog has died

WHO'S a clever girl? Chaser, a border collie who learned over 1000 words, died last week, aged 15. Chaser's exceptional vocabulary earned her the epithet "world's smartest dog".

Her owner, John Pilley, trained Chaser for up to 5 hours a day for three years, using 800 toys, 116 balls and various plastic items. He would show Chaser an object, say its name up to 40 times, then hide it and ask her to find it.

In a test of Chaser's lexical prowess, she was tasked with getting 20 toys one by one. Out of 838 trials she never got fewer than 18 out of 20 right. ▮ **Sam Wong**

Longevity

Anti-ageing's new hope

A treatment intended to slow the process of ageing has been launched as a supplement without clinical trials. **Graham Lawton** reports

COULD this be the start of a new way to fight ageing? A supplement designed to slow the ageing process aims to increase the number of healthy years we enjoy towards the end of our lives.

Launched for online sale in the US in July, the pill hasn't been through clinical trials. Instead, it is being marketed direct to the public as a dietary supplement named Rejuvant. Its makers claim it is the only scientifically validated anti-ageing supplement on the market.

The launch comes at a time of great excitement in longevity medicine. As previously revealed by *New Scientist*, numerous experimental drugs are in trials, and investors expect the field to become a huge industry.

By choosing to sell its product as a supplement rather than a drug, Florida-based firm Ponce De Leon Health (PDLH) has beaten many companies out of the gate, but only full clinical trials will be able to confirm whether the pill actually benefits people.

Living active lives for longer is now the focus of anti-ageing research

DEEPOL/PLAINPICTURE

Rejuvant contains alpha-ketoglutarate (AKG), which some studies suggest can extend the lifespan of worms and mice. It has been developed in two formulations: one for men that contains vitamin A, and one for women that includes vitamin D3.

> **"Some of us are concerned about companies leaping ahead without getting human evidence"**

According to PDLH, these combinations are potent extenders of healthspan – the years spent free of serious disease – in mice, while also lengthening lifespan. The reported improvements are, in theory, the equivalent of about five human years of healthy life.

The supplement was developed by feeding mice combinations of compounds identified as longevity extenders in previous animal studies. Researchers at the Buck Institute for Research on Aging in California assessed the mice for hallmarks of ageing such as frailty, hair loss, tremors and difficulty walking. They found that combining AKG with vitamins had the strongest effect on healthspan, and was linked with a boost in lifespan of two to three months.

AKG and vitamins A and D3 are considered "generally recognised as safe" for human consumption by the US Food and Drug Administration, but they haven't yet been assessed in combination.

"It should be safe, but it would be good to have data to show it's doing something good in a human before selling it," says Joan Mannick, chief medical officer of a different anti-ageing biotech firm, resTORbio. "I don't think we can assume that because it does something in a mouse it's going to do something in a human."

PDLH says its experimental results are under review for publication in a journal. Details aren't available for wider scrutiny yet, but the firm says its mouse experiments found significant epigenetic changes in the animals. This involves changes to methyl groups on DNA that help regulate the activity of certain genes. PDLH says it saw methylation patterns in older mice that resembled those usually seen in younger animals.

It also says it has evidence that AKG targets senescent cells: worn-out cells that have become a prime target in the renewed quest for anti-ageing treatments. Such cells pump out inflammatory proteins that contribute to ageing.

Rejuvant may also act through another key ageing process – the mTOR pathway that turns processes that protect against ageing on and off. Experiments in the worm *Caenorhabditis elegans* have previously shown that AKG influences this pathway, but PDLH has no direct evidence that its supplement does this in mice yet.

Safety trial planned

When PDLH CEO Tom Weldon announced his plan at a closed scientific meeting earlier this year, many researchers expressed concern about putting a pill on the market without human data on safety and efficacy.

Weldon is one of several PDLH executives taking the supplement. He says that, after a few months, he has seen a dramatic improvement in the levels of certain chemicals in his blood, including C-reactive protein, a sign of inflammation. But he warns that this is anecdotal evidence.

He says he decided to sell the pill as a supplement after realising that, at 63, he would be unlikely to see the product make it to market as a fully validated anti-ageing drug.

Janet Lord at the University of Birmingham, UK, says that, although there is good reason to believe that ageing can be slowed, "some of us are concerned about companies coming in and leaping ahead without actually getting the evidence in humans".

PDLH is preparing to begin an 80-person trial, primarily to confirm Rejuvant's safety. This will also look for epigenetic changes. ▮

Geology

Water may flow in giant canyon under Greenland ice sheet

Michael Marshall

A VALLEY longer than the Grand Canyon hidden under the Greenland ice sheet may carry flowing water. It could affect the ice sheet, causing parts of it to move more quickly or slowly towards the sea.

The hidden canyon was first described in 2013 by Jonathan Bamber at the University of Bristol, UK. It runs for at least 750 kilometres across northern Greenland. The Grand Canyon in the US is just 446 kilometres long.

However, Bamber's map of the canyon was incomplete because it was obtained by planes that carry ice-penetrating radar flying in straight lines. Bamber filled the gaps using a statistical method based on the average heights of surrounding bedrock. This made it look like the valley was blocked at several points. But he and his team suspected that the valley is continuous.

Now, Christopher Chambers at Hokkaido University in Sapporo, Japan, and his colleagues have developed a reconstruction of the valley that fills in the gaps on the basis of the canyon's shape instead (*The Cryosphere*, doi.org/c8xm). "We get this water pathway that links up and goes all the way down towards the coast," he says.

That implies there could be a trickle of liquid water along the canyon floor. "The base of the ice sheet is melting very, very slowly," says Chambers.

The liquid water could affect the stability of the ice sheet. If a thin layer of water consistently sits in the canyon, that would act as a lubricant and allow the ice to slide more quickly into the sea. But a rapid flow down the canyon would take this water away, slowing down the ice. "It's a potential problem for the simulations of the ice sheets into the future, because we need to know where the water is going," says Chambers. ▮

Analysis Social media

The facts about Facebook's fact-checking

The first big report on the tech giant's initiative to fight fake news says there is plenty of room for improvement, finds **Donna Lu**

MANCHESTER CITY COUNCIL
Fake news is not our friend.
We're working with more fact checkers globally, improving our technology and giving background information on articles.
facebook

JOEL GOODMAN/LNP/SHUTTERSTOCK

Facebook is using fact-checking firms to combat fake news

FACEBOOK is attempting to stop the spread of fake news on its site, but it needs to ramp up its efforts and be more transparent about whether they are working. That is the conclusion of a report released on Tuesday by UK fact-checking charity Full Fact, which details the first six months of a partnership with Facebook.

Full Fact is one of more than 50 fact-checking firms working with Facebook to review and debunk false content on the site. The tech giant started collaborating with fact-checkers in the US in December 2016, after criticism of its failure to stem the spread of fake news in the run-up to the presidential election.

Under the scheme, Facebook provides independent fact-checkers with content to review and rate. Fact-checked content is automatically marked on Facebook, so users are informed if they share a post that has been reviewed. Stories, images and videos that have been rated as false are still shareable but are shown lower in newsfeeds by Facebook's algorithm, with the aim of reducing their reach.

An analysis by Buzzfeed News last year found that the top 50 fake stories on Facebook in 2018 generated around 22 million total shares, reactions and comments.

Between January and June, a Full Fact team of seven people published 96 fact-checks chosen from a queue of content provided by Facebook algorithms.

80%

Reduction in a Facebook post's reach, once flagged as false

The posts they reviewed contained potentially harmful content, such as false statements about vaccines, and some had been shared more than 100,000 times.

But most of the queue provided by Facebook contained content that couldn't be fact-checked, such as statements of opinion and random links, including a swathe of Mr Bean videos. This highlights the difficulty in monitoring the more than 1 billion pieces of content posted to the platform each day. "Facebook's algorithms are not yet at a stage where they can reliably identify information that is inaccurate," says Will Moy, chief executive of Full Fact.

This is a blow for Facebook because, alongside other technology companies, it has said that artificial intelligence should be used to help tackle fake news. But AI doesn't seem ready yet.

Julia Bain at Facebook says the firm's algorithm sends content to fact-checkers based on metrics such as users flagging a post and disbelief expressed in its comments. After content is rated as false by fact-checkers, its reach on Facebook decreases by more than 80 per cent, says Bain.

But Facebook hasn't provided Full Fact with detailed information about the effect of their fact-checks on reducing false content. "We need more information to evaluate how well the programme is working," says Moy.

Firms such as Snopes have quit Facebook's fact-checking scheme and have similar criticisms about the platform's lack of transparency. Facebook has begun providing partners with reports on the number of fact-checks conducted and how often fact-checked articles are seen, says Bain.

Moy says the partnership has been a positive first step, echoing the views of other fact-checkers, but for it to have an appreciable effect, it is necessary to significantly step up both review speed and content volume.

"Misinformation travels a lot faster than the corrections do," says Michelle Amazeen at Boston University. Fact-checking can be effective but the risk is that people may believe false content to be true because it hasn't yet been labelled as debunked, she says. ▮

The archaeology revolution
More on how genetics is bringing new insights
newscientist.com/archaeology

Genetics

Origins of the Vikings

A major DNA analysis has found that the Vikings didn't only come from Scandinavia. Their story is far more intriguing, reports **Michael Marshall**

THE Vikings weren't all Nordic natives. They comprised multiple distinct groups of different peoples, according to a major study of ancient DNA.

"Viking genetics and Viking ancestry is used quite a lot in extremist right-wing circles," says Cat Jarman at the University of Bristol in the UK, who wasn't involved in the study. Many white supremacists identify with a "very pure Viking race of just people from Scandinavia, who had no influence from anywhere else".

In fact, the DNA evidence suggests the Vikings were the product of a diverse melting pot.

We know that the Vikings were a seafaring people from Scandinavia who were a major force in northern Europe from about AD 750 to 1050: the Viking Age. They are famous for their violent raids on the British Isles and elsewhere, and their epic sagas.

AF ARCHIVE/ALAMY

TV programme *Vikings* depicts the exploits of raiding warriors

To better understand their origins, Eske Willerslev at the University of Copenhagen in Denmark and his colleagues studied DNA from Vikings and their contemporaries (bioRxiv, doi.org/c8v7).

The researchers analysed DNA from the remains of 442 people from Europe and Greenland who lived between 2400 BC and AD 1600. This allowed them to reconstruct Viking populations as well as their movements.

"We have an embarrassment of riches in the archaeogenetics world at the moment," says Martin Richards at the University of Huddersfield, UK. "This is another very rich work, and the first one to focus on the Vikings. There's a huge amount of new data."

The team found that, in the centuries preceding the Viking Age, Scandinavian peoples acquired many new gene variants from elsewhere in Europe. This suggests a major migration from the region around what is now Germany into Denmark, Sweden and the rest of Scandinavia.

"Although the basic genetic pattern of Europe was established by the Bronze Age, around 4000 years ago, there were myriad migrations taking place across Europe in the subsequent millennia," says Richards. "The first millennium AD was a time of massive upheaval," partly because of the Western Roman Empire's collapse.

> "The DNA findings line up with other evidence that Viking societies were more advanced than thought"

It is a bit early to speculate on who the people who moved into Scandinavia were, says Richards, but we do know that invading nomadic Huns caused a lot of population displacement in Europe around this time.

The DNA also shows that not all Vikings were alike. There were three major groups, centred in Sweden, Norway and Denmark, and they sailed to different places. Danish Vikings tended to visit England, Swedish Vikings roamed the Baltic, while Norwegian Vikings went to Ireland, and further afield to Iceland and Greenland. The term "Viking" is therefore an umbrella term for several groups.

"It's always been an oversimplification, but I doubt if people are going to stop using it," says Richards. "Clearly there was a common pattern embraced by many coastal communities across Scandinavia, but equally across the whole region there were many people who had very little to do with it."

What's more, the study also found that some people buried in Viking regalia had distinctly un-Viking DNA, such as two belonging to the Sami people who now live in northern Norway, Sweden and Finland. "Viking identity isn't necessarily a genetic ancestry," says Jarman. "They had a couple of individuals who were buried as if they were traditionally Viking, but they had Sami DNA."

The DNA findings line up with newer archaeological evidence that Vikings lived in more advanced societies than previously thought, says Jarman.

"You have these centres that are really quite urban," she says, like Sigtuna in Sweden and Hedeby, which was part of Denmark but is now in Germany. It isn't clear how many people lived in them, but the towns had widespread trade, diverse populations and centralised organisation.

Willerslev's sample included 34 members of a Viking expedition buried at Salme in Estonia, along with their boats and weapons. Four were brothers, accompanied by a more distant relative. Many other members had similar genetic profiles. This implies that such expeditions were undertaken by groups of close relatives. Based on their expensive weapons and clothes, they were high-status.

The expedition may not have been a raiding party, as the Vikings were wearing ceremonial clothes and were "not really dressed for a fight", says Jarman. She says it may have been more of a diplomatic mission, as Viking leaders often formed alliances with one another. "You agree to support this particular person in that place if they agree not to attack you or whatever," she says. ■

New Scientist
Discovery Tours

SWITZERLAND

Explore dark & frozen matter: CERN & Mont Blanc

Particle physicist Kate Shaw and science journalist Laura Spinney will lead a fascinating and insightful tour focusing on CERN, home to the famous Large Hadron Collider, and Mont Blanc to investigate receding glaciers. Fall in love with the charming lakeside city of Geneva, famous for its watch-making, high quality chocolate and enchanting old town.

Tour highlights include:

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- Walking tour of Geneva's old town centre and beautiful cruise on Lake Geneva
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Machine learning

Brain-inspired chip could transform AI

Donna Lu

A COMPUTER chip inspired by the brain could pave the way for artificial intelligence with a broader range of abilities. The chip has been used to control an autonomous bicycle, but one day it might power self-driving cars and smart robots.

Shi Luping at Tsinghua University in China and his colleagues made the chip with hardware based on the structure of the human brain that can run two types of algorithm.

To date, most approaches to developing AIs fall into two camps. The first, and more common, type of algorithm is artificial neural networks, which are simplistic models of neurons designed for specific computer processing tasks such as recognising objects.

> "One day, this flexible computer chip might power self-driving cars and smart robots"

Then there are biologically inspired circuits, known as spiking neural networks, which are rarer. These aim to more closely replicate the human brain, with its billions of neurons that communicate via electric pulses. Whereas neurons in artificial neural networks can "fire" at different intensities, neurons in spiking neural networks are either on or off.

Shi's chip is built to deal with the operations required by both algorithms, so it is potentially more efficient.

His team has shown how the hybrid chip could be used in an autonomous bicycle. The bike combines several different algorithms for different tasks, allowing it to respond to voice commands, to self-balance, avoid obstacles, and detect and follow a person.

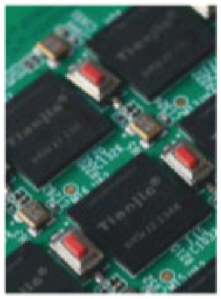
Its processor, known as the Tianjic chip, combined five different neural networks, including a spiking neural network that recognises voice commands such as "straight" and "speed up" (*Nature*, DOI: 10.1038/s41586-019-1424-8).

The algorithms were all trained before being loaded onto the chip, where they were run in parallel in the bicycle. Shi says the computer chip could be used for other applications including intelligent robots and self-driving cars.

Alessandro Oltramari at engineering firm Bosch says the hybrid chip may be suitable for a variety of tasks. "You really need to have an architecture that is complex enough, that can deal with different problems using different mechanisms," he says.

But more general AIs are still some way off, he adds. Although the Tianjic chip was effective for autonomous navigation in a bicycle, to prove its general ability, it would need to succeed at a range of totally different tasks, such as manipulating objects, playing games or holding a conversation.

Oltramari says the chip overlooks a third approach that may be required for artificial general intelligence: cognitive-inspired neural architectures. Instead of trying to replicate the anatomical structures of the brain, this aims to mimic the cognitive abilities of the human mind, such as its ability to pay attention, remember and make predictions. ▮



PEI ET AL., NATURE

A new computer chip has been used to control a self-riding bicycle

Pregnancy

Debate reignited over the placenta's microbiome

Jessica Hamzelou

STEVE ALLEN PHOTO/GETTY

The placenta supplies food and oxygen to a fetus

IS THE placenta home to communities of bacteria? Recent evidence that the organ has its own microbiome promised to rewrite our understanding of it, but now research suggests that the earlier experiments may have been contaminated.

Although the gut is known to host a rich, diverse community of bacteria, as well as viruses and fungi, the fetus and placenta had long been assumed to be sterile.

That picture started to change seven years ago, when evidence emerged that babies are born with a gut microbiome, which seems to start taking shape before birth. Then in 2014, a team led by Kjersti Aagaard at Baylor College of Medicine in Texas found low levels of bacteria in the placenta.

Julian Parkhill at the Wellcome Sanger Institute in Cambridge, UK, and his colleagues wanted to find out if the make-up of the placenta's microbiome might influence the outcome of a pregnancy. But as their research progressed, they came to a different conclusion: that the placenta doesn't seem to have a microbiome after all.

Parkhill and his team performed tests on samples of placenta taken from 578 women. In one experiment, they found that the same strain of the *Escherichia coli* bacterium was present in all of the placenta samples (*Nature*, DOI: 10.1038/s41586-019-1451-5). "That's impossible from a cohort of hundreds of pregnant women," he says. The bacteria must have come from the experiment kit, he says.

What Parkhill sees as contamination, Aagaard views as evidence of a microbiome. While the microbiome of the placenta might not be as rich and diverse as that of the gut, she says, it could still play an important role in birth outcomes and a baby's metabolic and brain development.

The debate continues. "Believe you me, I am as exhausted by the seemingly endless back and forth as anyone is," says Aagaard. ▮

INDIA

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Genetic privacy

DNA home testing worries

UK's data watchdog receives complaints about DNA testing firms

Adam Vaughan

THREE of the biggest home DNA testing companies have been the subject of complaints to the UK's data watchdog, figures released under freedom of information rules show.

Since January last year, the Information Commissioner's Office (ICO) received a total of 16 complaints about AncestryDNA, 23andMe and MyHeritage. The cases seem to have been relatively low level, but several necessitated action by the firms involved and required the ICO to raise concerns and advise on compliance with data protection rules.

Direct-to-consumer DNA testing companies are growing in popularity, with 4.7 million people in the UK estimated to have used a home DNA testing kit. Members of the UK parliament are probing what safeguards should be put in place to protect people who take such tests, some of which can tell people their risk of developing conditions such as type 2 diabetes.

Influential scientific groups have already told MPs that steps need to be taken to avoid negative outcomes, such as any anxiety caused when people receive their results. The groups also said that new laws may be required to make sure genetic data isn't sold on to third parties like insurance firms.

Of the complaints made to the ICO, 10 were about AncestryDNA, two about 23andMe and four about MyHeritage – the first two firms are based in the US and the last in Israel. They covered issues such as security, the use and disclosure of data and the right to prevent the processing of data.

ERIC BARADAT/AFP/GETTY IMAGES

23andMe is one of a number of home DNA testing services

The details of the cases weren't disclosed in the freedom of information release to *New Scientist*. But they probably involve isolated incidents of human error, rather than failures of procedures. That might be sending an email to the wrong person, or the loss or accidental destruction of small volumes of personal data, for example.

Since new European Union privacy legislation took effect in May last year, known as the General Data Protection Regulation (GDPR), biometric data has been designated as special category data, meaning it has additional legal protections.

4.7 million

People in the UK have used home DNA testing kits

GDPR probably raised awareness that you can complain about the use of genetic data, says Debbie Kennett at University College London.

It is likely that many more complaints are being made directly to companies, but those figures aren't published. The number of complaints seems low given the number of people estimated to have taken a DNA test in the UK, says Kennett.

"It's quite reassuring that the ICO is actually working as it should do, and there is this channel where people can submit complaints and have them investigated," she says.

Primates

New monkey species already threatened by deforestation

IT IS time to welcome another species to the primate family tree – but the Munduruku marmoset may already be under threat from deforestation in the Amazon.

Rodrigo Costa Araújo at the National Institute of Amazonian Research, Brazil, discovered the species in 2015. It has a distinctive white tail that sets it apart from most other Amazonian marmosets.

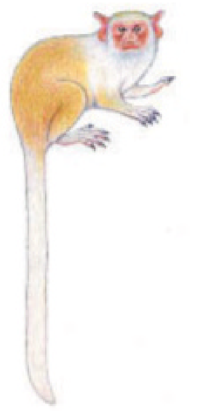
"I thought, 'Oh my God, they are different, they are really, really different'," says Araújo.

To entice monkeys out of the trees, he and his colleagues played an MP3 recording of other marmoset calls over a speaker while trekking through the rainforest.

During subsequent expeditions over the next three years, Araújo and his colleagues found that the patch of forest where they first found the white-tailed marmosets is home to clusters of the monkeys.

In order to prove that the monkeys represent a new species, the researchers killed five individuals for analysis under a permit provided by the Chico Mendes Institute for Biodiversity Conservation, the administrative arm of the Brazilian Ministry of the Environment. The monkeys' markings were the first thing that set them apart, but the team also examined their DNA.

Their genomes were all closely related but distinct from those of other known marmosets in the Amazon. This evidence, combined with data showing their unique distribution across a 55,000-square-kilometre area, helped to prove this was a new species. It has been named *Mico munduruku* (*PeerJ*, doi.org/c8vd).



STEPHEN NASH

The Munduruku marmoset has a distinctive white tail

The Amazon currently faces high levels of deforestation and urban development. Araújo warns that such practices threaten the monkeys' habitat. Mining and farming activity may also be a problem for the species.

Chris Baraniuk

Medical technology

Bionic eye helps people who are blind read letters again

Donna Lu

FIVE people who are legally classed as blind are testing a bionic eye. During a trial of the device, most of the participants were able to read individual letters. Although this is far from restoring perfect vision, it is a big improvement.

The bionic eye consists of glasses with an embedded camera and a microchip implanted behind the retina. Images beamed from the camera through the pupil are converted by the chip into electrical signals that are sent to the brain.

Participants in the trial have macular degeneration, which affects the macula, the central 5 millimetres of the retina that is responsible for the middle part of vision. In severe cases, this part of the vision is blurred or completely dark, making it impossible to read or recognise faces. The bionic eye, created by France-based firm Pixium Vision, effectively replaces this missing portion, although not in high definition.

The retina has millions of photoreceptors, each like a pixel in our field of vision. Trying to replicate them electronically is a challenge, but implants are improving, says Rachael Pearson at University College London, who wasn't involved in the research. The image created by the implant is only 378 pixels in total.

Individuals with eye conditions can lose a huge number of photoreceptors before they notice symptoms. "Being able to replace and do the job of a relatively small number may still give useful vision back," says Pearson.

All the trial participants have dry macular degeneration, a form of the condition that accounts for 90 per cent of all cases. It cannot currently be treated or reversed.

Two clinical trials of the implant are under way in Pittsburgh and Miami in the US, and a larger study in Europe is planned for next year. ▮

Commentary **Thirty Meter Telescope**

Hawaii telescope row

It's time to stop ignoring local protests on Mauna Kea, says **Haunani Kane**

WESTEND61/GETTY

Thirteen telescopes have already been built on Mauna Kea

FOR over two weeks, *kia'i mauna* (Hawaiians and their allies) have been protesting on the access road to the proposed site of the Thirty Meter Telescope (TMT) on Mauna Kea, a sacred peak on Hawaii Island. If built, the telescope could help us understand the formation of planets and galaxies. But the history of telescopes on Mauna Kea is deeply upsetting.

Mauna Kea is the tallest mountain in the world from its undersea base and an excellent place to make astronomical observations. It is already home to 13 telescopes, however the scientific advances these have achieved have been clouded by neglect of the site's culture and history.

In Hawaiian tradition, Hawaii Island is the eldest child of sky father Wākea and earth mother Papahānaumoku. Mauna Kea is the umbilical cord that connects Hawaii to the heavens, and connects humans to land.

But despite previous public protests, the Supreme Court of Hawaii ruled in 2018 that construction of the TMT could continue on Mauna Kea. Part of the reasoning behind the ruling was that adding another telescope to the site wouldn't have much further impact upon the mountain's natural and cultural resources, due to the degradation already caused by constructing the existing telescopes.

> **"The best way forward is to acknowledge there is a place for culture in the pursuit of knowledge"**

Kia'i mauna disagree: we see a fourteenth telescope on the site as a further desecration of our land and culture.

This culture isn't a relic, it is alive today. I am the science director for the Polynesian Voyaging Society, and I have been trained in the ways of my ancestors to use the heavens, oceans and mountains to navigate across the ocean by canoe. Technology can fail at sea, and using our minds and the ancestral teachings to seek an island's mountain peaks is a better guide than any GPS.

This training has played an important part in the education of Hawaiian scientists like me. Throughout my research into the impacts of sea level rises on Pacific islands, I have needed to collaborate with others and consider multiple perspectives to find my way – just as I have when voyaging by canoe. Surviving at sea requires resilience and compromise, two essential traits in scientific research.

But while I and many scientists of my generation feel our culture informs our research, astronomy on Mauna Kea stands apart as something divorced from the ethos of Hawaii. The best way forward would be to acknowledge there is an important place for culture in the pursuit of knowledge. Scientific efforts must incorporate *aloha 'aina*, our love of the land, into their construction projects.

All that is needed is for those in charge of the observatories to value our heritage as much as they do the celestial objects they observe with their telescopes.

Some astronomers have spoken out in support of the *kia'i mauna*. But if universities, the state of Hawaii and the *kia'i mauna* can't find a way forward, those behind the TMT should ensure they don't go on to repeat the mistakes made in Hawaii elsewhere. ▮

Haunani Kane is an instructor of oceanography at the University of Hawaii

Fossils

Ancient predator on show

Exquisite Chinese fossils on display in the UK

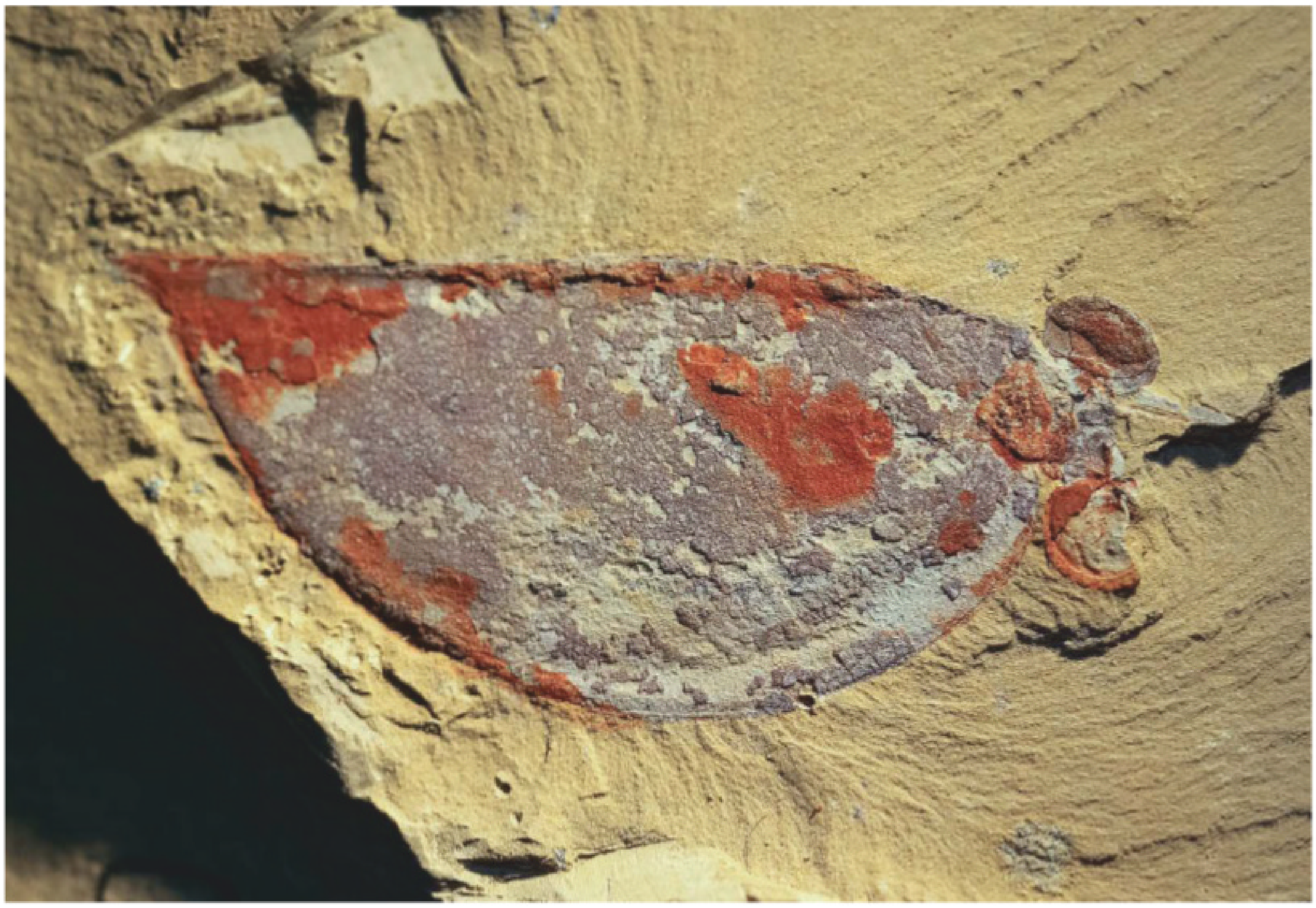
Graham Lawton

MORE than half a billion years ago, this stalk-eyed minibeast (*Isoxys auritus*) cruised the seas in what is now Yunnan, China.

This remarkable fossil is one of 55 from the Chengjiang deposit on loan to the Oxford University Museum of Natural History, most of which have never been seen outside China before.

The fossils date back more than 500 million years to the Cambrian explosion, an evolutionary big bang that gave birth to modern ecosystems and all the basic types of animal we see today. The Chengjiang deposit has become famous for its exquisite specimens, many of which are changing our understanding of how animals evolved.

***I. auritus* was related to insects and crustaceans, and was probably a predator. This fossil is on display as part of the museum's First Animals exhibition.**



OXFORD UNIVERSITY MUSEUM OF NATURAL HISTORY

Machine learning

AI could lower household energy bills

ARTIFICIAL intelligence is being used to make the UK's forecasts for solar power generation more accurate. This could lower energy bills for consumers as well as carbon emissions.

The country's energy system is becoming more reliant on renewable sources of electricity that tend to have a variable output, like solar. About 36 per cent of the UK's electricity was generated from renewables in the first quarter of 2019.

"The growth in solar was much, much more fast-paced than anyone anticipated," says Cian McLeavey-Reville at National Grid Electricity System Operator (ESO), which balances supply and demand in England, Scotland and Wales.

But solar panels are connected to local distribution networks rather than the national network, making it difficult for National Grid ESO to monitor their activity. Combined with the trickiness of forecasting the weather, that makes forecasting supply from solar panels difficult, says McLeavey-Reville.

Now National Grid ESO has teamed up with the UK's Alan Turing Institute to make more accurate solar power forecasts. Previously, these were based on two pieces of data: installed solar power capacity and the amount of the sun's energy that hits Earth.

"While this simple model can work relatively well for forecasts at very short times ahead, the accuracy degenerated quite rapidly," says Andrew Duncan at the institute.

> "Solar power forecasts for seven days' time instantly became about 10 per cent more accurate"

Duncan helped build a machine learning model that trained itself on scores of variables, including temperature and technical specifications of the solar panels. These were fed into an algorithm to produce forecasts of solar power entering the grid.

Forecasts for seven days' time instantly became about 10 per cent more accurate. Combining this with further modelling made those forecasts 33 per cent more accurate.

This is good news on two fronts. Balancing rapid changes in supply is expensive because reserve power stations suddenly need to be called on. Such balancing costs up to £1 billion a year, which is ultimately paid for through household energy bills. Better forecasting could reduce that by as much as £50 million. It should also lower carbon emissions, since most reserve power plants burn fossil fuels.

Adam Vaughan

Sexual reproduction

Jellyfish sperm with stingers that fire inside females

Michael Marshall

FEMALE *Tripedalia cystophora* box jellyfish are stung from the inside by packets of sperm. The tiny stinging structures may boost reproduction by anchoring sperm cells in the body of females.

Unlike most jellyfish, *T. cystophora* copulates, which means the eggs are fertilised inside the female, rather than out in the water. Anders Garm and Sandra Helmark at the University of Copenhagen in Denmark have now shown that *T. cystophora* sperm are unusual in that they come in packages equipped with stinging structures called cnidocytes.

The sperm cnidocytes shouldn't hurt the female, says Garm. "They are of a type without the penetrating arrow and without poison." Instead, they seem to anchor the sperm inside the female during fertilisation (*Journal of Morphology*, doi.org/c8vc).

This finding follows on from a 2015 study in which Garm and his colleagues looked at the only other box jellyfish known to copulate: *Copula sivickisi*. Not only do the sperm packages of this species also have cnidocytes, but the female sex glands carry them too.

Garm says this may be because, after fertilisation, *C. sivickisi* releases embryos to develop outside the body. The stinging cells may help protect these from predators. In contrast, female *T. cystophora* keep their fertilised eggs inside their bodies until they have developed. This means the fertilised eggs don't need to be armed with protective cnidocytes.

The species differ in that *T. cystophora* only mates rarely, so females take more care of each set of offspring. In contrast, *C. sivickisi* is more prolific, rapidly releasing a set of fertilised eggs and mating again within days. "The two strategies each have their advantages," says Garm. ▮

Technology

Soothing smartwatch app improves exam results

Donna Lu

EXAMS can make the heart race for even the most well-prepared candidate, but a simple smartwatch app could help alleviate the stress. The app produces a slow, soothing tapping that seems to help people perform better in situations filled with anxiety.

Jean Costa and his colleagues at Cornell University in New York created an app that reacts to people's heart rates by producing a slow, light tapping on the inner wrist of a smartwatch wearer.

They tested the app, called BoostMeUp, on 72 college students who were given two maths exams under pressure, and found that slow taps reduced anxiety and improved test performance.

A smartwatch app seems to keep you calmer during exams

Other studies have suggested that techniques like meditation can reduce stress, which apps like Headspace and Calm try to help with. "But in many situations we need something in the moment," says Costa.

During a practice maths test, the team used smartwatches to measure the students' baseline heart rates. In subsequent tests, the watch gave half of the people a wrist tapping that was 30 per cent faster than their baseline heart rate, while the other half received tapping that was 30 per cent slower than their baseline.

After all the tests, participants filled out questionnaires to assess their levels of anxiety. Those who were given faster taps reported higher levels of anxiety compared with the slow-tapping group. The fast-tapping group also did worse on the test of 36 questions, answering 0.58 more questions incorrectly on average compared with when they had no feedback. The slow-feedback group answered 1.75 more questions correctly when the tapping was on (*Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, doi.org/c8vb).

1.75

People using an app got this many extra exam questions right

Karin Petrini at the University of Bath, UK, thinks improving cognitive performance like this is exciting, but isn't convinced that the results are conclusive.

There was only a small reduction in anxiety for the slow-tapping group, but a greater improvement in cognitive performance. This calls into question whether the improvement was linked to changes in anxiety, says Petrini.

Costa says the app may be hard for students to use in real exams, where technology such as mobile phones and smartwatches are banned. But he says it could be useful during a job interview or while public speaking, for example.

Another approach, tested by Asma Ghandeharioun at the Massachusetts Institute of Technology and her colleagues, plays breathing sounds slightly slower than someone is breathing. Her team found this made people breathe deeper and slower, which has been shown to reduce blood pressure.

Other apps have been trialled as a way to track students' mental health, such as StudentLife, which uses a smartphone to monitor social interaction, physical activity and sleep patterns. ▮

ZINKEVYCH/GETTY

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newscientist.com/article-topic/wearables/

Aerodynamics

Dark feathers give birds a lift when they heat up

HARRY COLLINS/ALAMY STOCK PHOTO

HAVING dark feathers may help birds fly more efficiently as sunlight heats their wings and the surrounding air, increasing airflow.

Svana Rogalla at Ghent University in Belgium and her team thermally imaged an osprey (pictured) and saw that its dark feathers get warmer than light ones, probably because they reflect less light.

To see how this might affect flight, the team put stuffed wings of ospreys, gannets and back-blacked gulls in a wind tunnel. These were then heated with infrared light bulbs similar in intensity to being outdoors on sunny and cloudy days.

They exposed the wings to wind speeds of 6, 12 and 18 metres per second, similar to the birds' natural flight speeds. "We wanted to simulate flight under realistic conditions," says Rogalla.

Darker feathers heated up much more than light feathers (*Journal of the Royal Society Interface*, doi.org/c8t4). "We found temperature differences of about 9 degrees between black and white," says Rogalla. "We would even find these temperature differences in the same wing."

The finding suggests that a common wing pattern – white feathers where the wing attaches to the body and black feathers at the tip – could increase lift while flying.

The temperature difference between the light and dark feathers creates convective currents in the air above the wing that move from the cooler base of the wing to the darker tips, says Rogalla. This boosts the airflow over the wing, which may make flight more efficient. **Donna Lu**

Astrophysics

Hurtling star proves Einstein right again

EVEN at the centre of the Milky Way, Einstein's laws rule. Measurements of light from a star that orbits close to our galaxy's central supermassive black hole can't be explained by classical views of gravity and instead require Einstein's general relativity.

General relativity predicts that starlight should lose some energy as it travels through the powerful gravitational field of a black hole. That energy loss is expected to stretch the wavelength of light from stars near huge black holes, making them look more red.

Standard, or Newtonian, gravitational theory doesn't predict this. No one really expects Einstein's theory to be wrong at this scale, but if its predictions were off by even a little bit, it might point the way towards new physics.

Tuan Do at the University of California, Los Angeles, and his colleagues used 24 years of observations of a star called S0-2, which orbits relatively close to our galaxy's central supermassive black hole, Sagittarius A*. The data included measurements of the star's colour and position, and the team calculated its velocity from measurements of its position over time.

"When the star becomes redder, it also looks like it's moving away from us faster than it would without this gravitational redshift," says Do.

The team needed 24 years' worth of data to nail down the star's orbit and make sure this wasn't tainting the colour measurements.

Do and his colleagues found that S0-2 appeared significantly redder than we would expect if its light wasn't being stretched by relativistic effects (*Science*, doi.org/c8tt). "Einstein was right, for now," says Do. **Leah Crane**

Ecology

Tree stump kept alive by nearby trees

A TREE stump that should have died is being kept alive by neighbouring trees, which are funnelling water to it via their roots. The finding adds weight to the idea that organisms can work together for the benefit of a forest.

Sebastian Leuzinger and Martin Bader at the Auckland University of Technology in New Zealand saw a tree stump near Auckland with living tissue growing from it.

BADER AND LEUZINGER

Wondering how it could survive without foliage, they put water monitors in the kauri (*Agathis australis*, pictured) stump and in two nearby trees of the same species. In healthy trees, water flow is largely driven by evaporation through their leaves.

Over the following weeks, they saw a pattern in the water flow in the trees. When the neighbouring trees evaporated water through their leaves during the day, water movement in the stump remained low. But when the trees were dormant in the evening, water circulated through the stump (*iScience*, doi.org/c8t2).

Without leaves, the stump's water flow was bound by the movements of its neighbours.

Combined with the fact that fungi and trees exchange nutrients, this finding undermines the idea of trees as individuals. "That dramatically changes our view of forest ecosystems as 'superorganisms'," says Leuzinger. **Ruby Prosser Scully**

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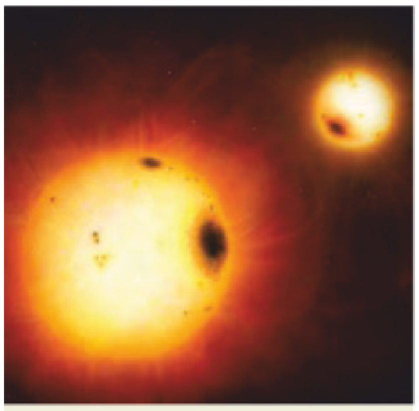
Really brief


MARK GARLICK/SCIENCE PHOTO LIBRARY

Something is up with the stars

Two white dwarf stars seem to be the wrong temperature. Physicists found that the pair are twirling around one another at an incredibly fast rate, but neither is the temperature we expect. The smaller one is colder and the larger one is hotter (*Nature*, doi.org/c8t7). We don't yet know why.

Light pollution helps virus spread

Birds are the main host of West Nile virus, and outbreaks among infected sparrows are 41 per cent more likely if the birds are exposed to light pollution (*Royal Society B*, doi.org/c8t8). The virus is transmitted from birds to humans by mosquitoes and it can be fatal in rare cases.

Tiny capsules motor around the body

Self-propelled capsules that shed their outer shells have been shown to linger long enough in mouse intestines to deliver drugs directly to tumour cells. The microrobots could one day be used as targeted treatments for cancers in hard-to-reach places in the human body (*Science Robotics*, doi.org/c8t9).

Climate change

Global warming has no recent parallel

THE global warming caused by humanity since the industrial revolution has been found to be unprecedented in the past 2000 years, in the latest blow to a common climate change denier myth.

Earlier hot and cold periods over the past two millennia, such as the "Roman warm period" that ended around the year AD 750, were previously thought to be global phenomena. That has led some to suggest that the current phase of warming could be a natural trend akin to these past fluctuations.

Now Nathan Steiger at Columbia University in New York and his colleagues have reconstructed temperature records for the past 2000 years from proxies including tree rings, coral and glacier ice.

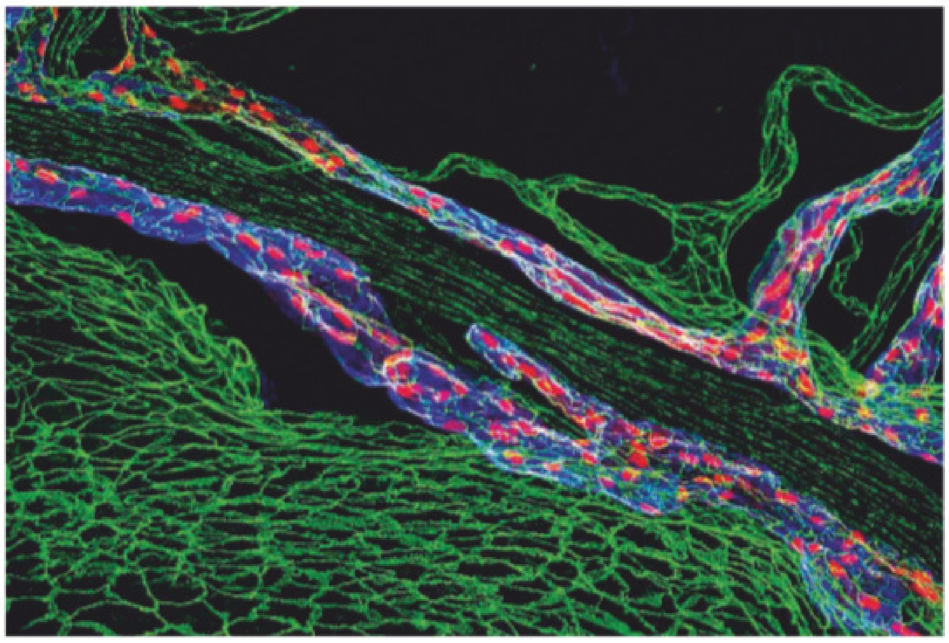
The team has found evidence that four past natural fluctuations were actually regional events. They didn't span the globe simultaneously, but often took centuries to move around the world.

The lowest temperatures of the Little Ice Age, for example, were recorded in the 15th century in parts of the Pacific, the 17th century in north-western Europe and south-eastern North America, and not until the 19th century elsewhere in the world.

By comparison, the rise in temperatures over the past two centuries has been felt across 98 per cent of the planet, reaching every corner except Antarctica (*Nature*, doi.org/gf5fmp).

Steiger says the findings should scotch arguments made by those who don't believe climate change is happening. **Adam Vaughan**

Anatomy



The brain's waste disposal system for flushing out toxins

WE NOW know a major route for clearing substances from the brain, and it may help us treat age-related conditions like Alzheimer's disease.

Where cerebrospinal fluid enters and exits the brain has been a long-standing enigma, says Gou Young Koh at the Korea Advanced Institute of Science and Technology in South Korea. In 2014, a network called the meningeal lymphatic vessels (pictured) was found to play a part in flushing out excess proteins.

However, the brain's complex structure meant it remained unclear where most of this drainage occurs.

Now Koh and his colleagues have used dye and tracer quantum dots to follow the flow of cerebrospinal fluid as it left the brains of mice. Brain scans showed that the basal meningeal lymphatic vessels let cerebrospinal fluid move in and out of the brain at the base of the skull, but not at the top.

Animals that were 2 or more years old drained about half as much through these vessels as those aged 3 months (*Nature*, doi.org/c8t6). This probably has implications for brain health. In Alzheimer's, for example, proteins build up in the brain and may cause damage. Boosting drainage may help treat such neurodegenerative disorders. Chelsea Whyte

(RIGHT) J HOON AHN AND HYUNSOO CHO/INSTITUTE FOR BASIC SCIENCE CENTER FOR VASCULAR RESEARCH, DAEJEON, SOUTH KOREA

Electronics

Flexible battery works even when stretched

A BATTERY that can conduct electricity and retain its charge when distorted could power flexible devices.

Nicholas Kotov at the University of Michigan and his colleagues have developed a conducting component for a lithium-ion battery that maintains conductivity even when stretched to three times its initial size.

Layers of negatively charged gold nanoparticles are alternated with positively charged layers of polyurethane – usually used to make things like hose pipes. As the battery is stretched, the gold nanoparticles self-organise into pathways, allowing them to continue conducting electricity.

The team tested the performance of the conductor in a battery with a lithium electrolyte. After 1000 cycles of use and recharge, it retained 96 per cent of its capacity. But this was lower if the battery was constantly in a stretched state: under those conditions it retained only 72 per cent of its capacity after 10 cycles. Once the strain is released, its capacity increases again (*Science Advances*, doi.org/c8v3).

Kotov envisages the battery being used in wearable or implantable devices. **DL**

Internet restrictions

The lowdown on shutdowns

Governments are increasingly cutting off the internet, saying this will curb violence. It mostly does the opposite, reports **Donna Lu**

MOHAMED KHIDIR/XINHUA/EYEVINE

Protests in Sudan against the military junta led to it switching off the internet

IN EARLY June, protesters took to the streets of Sudan's capital, Khartoum, to demand a civilian-led government. Shortly afterwards, Sudan's ruling military junta turned off the internet.

This isn't an isolated incident. There have been more than 100 internet shutdowns around the world this year already. Not a month has gone by without one in effect somewhere. And the tactic seems to be growing in frequency.

Governments usually claim the measure is taken to prevent people from using social media to coordinate violent protests or riots. But growing evidence suggests that shutdowns aren't effective for this and also have other negative effects.

There are essentially two ways to cut off the internet. The first is a routing disruption, which disconnects an entire network, as used recently in Mauritania.

The second is packet filtering, which blocks requests to access certain websites – for example, any address containing the word "Facebook". These selective shutdowns are used to seal off certain services, as happened in Chad in 2018, after the president recommended reforms that would enable him to stay in power until 2033. Blocked platforms included Facebook, Twitter and WhatsApp, which were only reinstated a few weeks ago after 16 months.

Both these types of shutdowns involve internet service providers (ISPs) taking orders from a government. For this reason, they mostly occur in parts of Africa and Asia where government transparency is low.

The first major episode came in 2011, when the Egyptian government cut off the internet and mobile networks for five days during the Arab Spring. But it wasn't until 2016 that some African governments began to implement shutdowns regularly, beginning when the Republic of the Congo blocked all telecommunications for a week during its presidential election, says Julie Owono at Internet Without Borders in France. "It's even countries which have never had censorship issues, like Benin in West Africa," she says.

Globally, there have been 115 shutdowns so far this year, says Melody Patry at digital rights advocacy group Access Now. The organisation has been monitoring shutdowns for several years. By its count, there were 196 in 2018, up from 75 in 2016 (see graph, right).

To understand shutdowns and their impact, researchers need to be able to detect and track them, but this isn't easy. Sometimes, all it takes to turn off the internet is a phone call, "so there is no paper trail", says Jan Rydzak at Stanford University in California.

A routing disruption can be spotted as a local drop in web traffic. But detecting packet filtering is more difficult, and requires active probing, for example sending information to a network and seeing what happens.

Rydzak has studied India, which has had more local shutdowns than anywhere else in the world: 134 in 2018. The reasons for many of these haven't been explained, but those that are officially acknowledged are usually said to be necessary for stifling violent collective action, says Rydzak.

However, his research suggests that blocking access to the internet and social media seems to achieve the opposite. Analysing 22,891 protests in India between 2016 and 2017, Rydzak found that local internet shutdowns tended to be associated with an escalation of riots and protests. "Riots disproportionately increased in number in conditions of an information vacuum," he says.

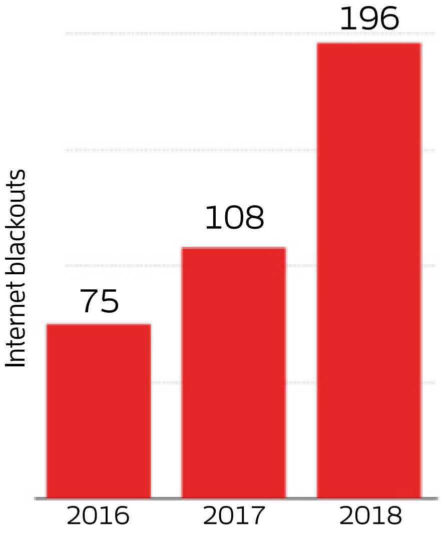
Rydzak thinks this is because shutdowns can push people towards violent tactics that rely less on coordination.

"Rumours don't stop when the internet is being cut off and actually that can escalate conflicts even further," says Patry.

While many shutdowns coincide with civil unrest, they are also increasingly occurring during elections. Both Patry and Owono say they have noticed a recent rise in officials saying that shutdowns had been implemented as a way to stop the spread of misinformation.

It is certainly true that hate speech and fake news can circulate on social media. Last year, a spate of lynchings in India, for example, was reportedly fuelled by false rumours spread via WhatsApp.

Estimates suggest the number of internet shutdowns around the world is on the rise. There have been 115 already in 2019



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At face value, the spread of false information may provide a justification for temporary shutdowns. But Owono says the concern is that, in reality, governments are using them as an excuse for censorship. Closing social media may be a way for a corrupt government to stifle transparency ahead of elections.

In other cases, shutdowns may be a tool to conceal human rights violations. A study of network disruptions in Syria found that these tend to coincide with significantly higher levels of state repression, notably in areas where government forces were actively fighting rebels.

Similarly, Human Rights Watch has denounced shutdowns in Rakhine and Chin states in Myanmar, where there is conflict between the state military and an armed local group.

But shutdowns aren't always political. Algeria, Iraq and Uganda have all temporarily shut down the internet during high school exams, ostensibly to prevent questions being leaked. In Brazil, judges enforced brief shutdowns of WhatsApp in 2015 and 2016 after the company didn't comply with requests for data as part of a criminal investigation.

However, while shutdowns are clearly a tempting measure for many governments, they aren't without costs. "Anytime there's a disruption in the internet or in mobile networks, it's going to have a major impact on businesses," says Darrell West at the Brookings Institution in Washington DC.

> **"India has had more local internet shutdowns than anywhere else in the world: 134 in 2018 alone"**

Examining the impact of 81 short-term shutdowns in 19 nations from July 2015 to June 2016, West found an estimated total GDP loss of $2.4 billion.

Disrupted communications hit healthcare too. Doctors in rural Cameroon, for instance, sometimes use WhatsApp to coordinate supplies of medicines, and shutdowns hamper this.

But like almost every internet restriction, there are ways around a partial shutdown. Internet Without Borders provides people with information on how to use tools such as virtual private networks or the Tor browser to circumvent a social media blackout. These mask a person's browsing activity, preventing governments from restricting the content they can access based on their geographical location.

Legal action can work too. "Sometimes you do have constitutional protections that make a shutdown illegal," says Patry.

In January, a Zimbabwe court ordered internet services to be restored following a challenge from human rights lawyers. And in June, a Sudanese lawyer successfully challenged a national telecoms operator to restore the internet, which has resulted in services gradually being restored. Patry says legal challenges like this will be increasingly used to hold authorities accountable.

But in some cases – such as when governments are handling the aftermath of a terrorist attack (see "Living through a shutdown", left) – the most effective measure may be to demonstrate to governments that shutdowns simply don't fix the problem of violence, and may in fact make it worse.

"I think it's important to target the self-interest of these governments," says Rydzak. "We need to show them that, for their own purposes, shutdowns are not the right way to approach societal problems." ▮

Living through a shutdown

On 21 April, several places in Sri Lanka were hit by terrorist bombs, with more than 250 people killed. At the time, I was holidaying in Sri Lanka with friends.

News alerts pinged on our phones around 10 am. We messaged our families to let them know we were safe, before cautiously heading out for the day. We were in Galle, about 2 hours' drive south of the capital, Colombo, where the first bombs struck.

In the early afternoon, while we were at a beach on the southern coast, my partner made a WhatsApp call to his mother, who is Sri Lankan, to get updates on the security situation. Fifteen minutes later, his WhatsApp messages stopped going through. We later realised that some social media platforms had been blocked – ostensibly to stop the spread of fake news and wild speculation. There were fears of violent reprisals.

Facebook, WhatsApp and Instagram were down for nine days. Notifications came through, but messages couldn't be loaded. Twitter was unaffected. We relied on word-of-mouth local advice for updates on the nationwide curfew. Whether or not the shutdown effectively curbed misinformation, it made communicating with concerned friends and family difficult. DL

Working hypothesis

Sorting the week's supernovae from the absolute zeros

▲ Bad jokes

Why did the awful joke seem funnier when other people were laughing? Because a study found it to be so. Ha!

▲ Forest walks

A step backwards for progress. Medi Bastoni is walking 800 kilometres backwards to raise awareness about forest preservation in Indonesia.

▲ Asteroids

Armageddon it was not. An asteroid called 2019 OK passed unusually close to Earth and was spotted only hours before. Luckily there was no collision so 2019 is OK, for now.

▼ Imperial units

UK politician Jacob Rees-Mogg has told his staff to use imperial units. We find it hard to fathom (around 1.8 metres) too.

▼ Hoverboards

It went quickly from above board to overboard when Franky Zapata splash landed in his attempt to cross the English Channel on a hoverboard.

SYLVAIN LEFEVRE/GETTY IMAGES, TOP: TOM CHANCE/GETTY

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The Folio Society

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Eating locally isn't always greener, says **James Wong** **p24**

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Utopians and realists agree the economy is broken **p30**

Culture columnist
Helen Marshall explores sci-fi slants on modern times **p32**

Comment

The 'I' in reality

To make progress in understanding the world, we need to grasp what part we play in making it, says **Richard Webb**

Richard Webb is executive editor at *New Scientist*

JOSIE FORD

FULL disclosure: I am a hypocrite. Two weeks ago, I wrote a *New Scientist* lead article about the urgent need to find alternatives to flying. Last Friday, I boarded a plane from London to Pisa, Italy, for a scientific conference that, at first glance, would almost certainly fail the "necessary" test.

In my defence, one of the themes of the conference, organised by the Foundational Questions Institute (FQXi), was the extent to which intelligent agents control their actions – and I did offset my emissions. What's more, I left the convention feeling that something quite important was stirring in the Tuscan hills.

At its heart is the mystery of life: how atoms and molecules come together to make stuff that can self-sustain, make decisions, influence and exploit its environment, and be conscious. Physics can't explain that. A few months ago, physicist Paul Davies, who presented at the conference, proposed in these pages that better, information-based physical theories might be the key to resolving the conundrum (2 February, p 28).

Maybe. But the problems go deeper. Our most basic theory of reality, quantum mechanics, is beset by the problem of conscious observation, which in some way seems itself to interrupt reality and perhaps determine its evolution – with potentially nonsensical consequences.

My brain overheats when confronted with these problems, and I was glad to learn at the FQXi conference that I am not the only one. But it is becoming clear that we will only make progress in fundamental physics and other fields by working out where the "I" is in reality.

Ideas are out there. On page 34 of this issue, for example, cognitive scientist Donald Hoffman presents his own evolutionary theory of how our perceptions necessarily cloud our ability to see what is truly what.

Conferences such as FQXi provide an opportunity for researchers from different disciplines to compare notes. What struck me observing them was how much work there is to do even just to define concepts such as agency, free will, consciousness and intelligence, and how they interrelate. Maybe physicists can help, though one early attempt – the integrated information theory of consciousness – has come under fire for allowing some pretty strange definitions of what counts as conscious.

For the very small amount it is worth, I am sceptical we will ever develop a comprehensive and objective theory of first-person, subjective experience. The lesson from other realms of enquiry, for example Gödel's incompleteness theorems in maths, is that logical systems blow up when trying to explain themselves.

But I am glad that people are trying. As we develop artificial intelligences and ask ourselves about their limits and dangers, the pay-offs of a better understanding of this relationship between conscious experience and the physical world could be huge.

It will take a different application of agency and intelligence to solve climate change (I will take the train next time). But figuring out how we relate to the world around us on a basic level is necessary, too. ■

#FactsMatter

Are food miles important?

Cutting the transport distance from farm to fork seems a sensible and straightforward way to lower carbon emissions. But it's not that simple, writes **James Wong**

James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, he shares his tiny London flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

James's week

What I'm reading

A lot of claims on Twitter purporting that modern fruit varieties are 100 times richer in sugar than their ancestors. Spoiler: this is essentially biologically (and thermodynamically) impossible.

What I'm watching

The new season of Stranger Things, *back to back.*

What I'm working on

I am trying (rather unsuccessfully) to sort out my work-life balance, mainly by tending to my vast collection of houseplants.

This column appears monthly. Up next week: theoretical physicist Chanda Prescod-Weinstein

THE popular narrative with food is simple: "eating local" is one of the best ways to shrink your carbon footprint. This is because food miles are a handy proxy for overall sustainability, as transporting harvests across the planet is a key driver of carbon emissions. It is a story that is as pervasive in the foodie media as it is intuitively plausible, but how reliable is it?

Well, it is indeed true that the food sector uses a lot of energy, contributing 20 to 30 per cent of all greenhouse gases. But how much of this is directly down to moving food around the globe from farm to fork? Perhaps less than you might think.

In one of the most comprehensive studies, researchers at Carnegie Mellon University in Pennsylvania report this to be just 4 per cent (thus making up as little as 0.8 per cent of the average carbon footprint of someone in the US). Echoing other research from around the world, which suggests transport generates just 4 to 6 per cent of the food system's carbon footprint, the study found that most emissions were actually generated from other aspects of food production, such as agriculture, processing and cooking.

To put this in context, the US Department of Agriculture found that household kitchen appliances generated nearly seven times as much carbon emissions as food transport. This figure is particularly pertinent considering that typical estimates of the length of US food supply chains aren't exactly insignificant, coming in at about 2400 kilometres.

In fact, considering all aspects of our food system – whether farming, processing, packaging, transport, retail, food services and households – it was the end consumer that used by far the most energy. Transport? The least.

OK, so food miles may not be the largest driver of our food system's carbon emissions, but surely every little bit helps when it comes to reducing our carbon footprint? The tricky thing is that cutting transport distance by swapping to a more local producer can often involve an environmental trade-off as the carbon emissions of agricultural systems can vary wildly.

One UK government study found that tomatoes trucked hundreds of kilometres from sunny Spain had a carbon footprint that was less than a third that of those grown in heated glasshouses in the chilly UK. Conversely, it found that the opposite was the case for crops like potatoes, where the carbon emissions of production were similar, meaning transport from further afield had a greater overall impact. In contrast to the simple "local = more eco-friendly" narrative, the authors therefore concluded that: "A single indicator based on total food kilometres travelled would not be a valid indicator of sustainability."

"Tomatoes trucked from Spain to the UK had lower emissions than those grown in heated glasshouses in the chilly UK"

TOPAE/SHUTTERSTOCK

When it comes to our carbon footprint, transport methods vary enormously too. For example, as air freighting produces more than 75 times more emissions than sea freight, shipping food to the UK all the way from South-East Asia would involve far less carbon than the same product popped on a short flight from Italy. In this context, a single shipping food mile is the equivalent of almost 8 road food miles and over 75 air food miles, making the concept of distance as a direct indicator of emissions highly problematic.

Finally, even within the same transport method, the concept of food miles can belie the true complexity of calculating carbon emissions, such as economies of scale. In a study at the University of Bath, UK, researchers aimed to compare the emissions when consumers bought fruit and vegetables directly from local farms or through an organic box delivery scheme. The box scheme involved a carbon-hungry system of cold storage, packing and transport to and from a regional hub, on top of delivery to the consumer's door. Yet despite this, the efficiencies of scale meant total emissions were still lower than if all these consumers made individual car trips direct to the farm of 6.7 kilometres or more.

So is eating local really a better option? It depends. There are many reasons why you might be choosing to do so, aside from environmental concerns. Indeed, there are many other ways to measure environmental impact other than carbon emissions. But when we look at the evidence, only one thing is clear: food miles alone really aren't a good proxy for sustainability. In fact, sometimes they are incredibly misleading. While we can't discount them entirely, we should view them in the context of a suite of other factors, recognising that they often make up a tiny fraction of food's carbon impact. ▮

Goodbye fishbowl helmet

The next generation of astronauts will be wearing a zip-uppable "space hoodie"

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New
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Editor's pick

The food advice I needed came from a song

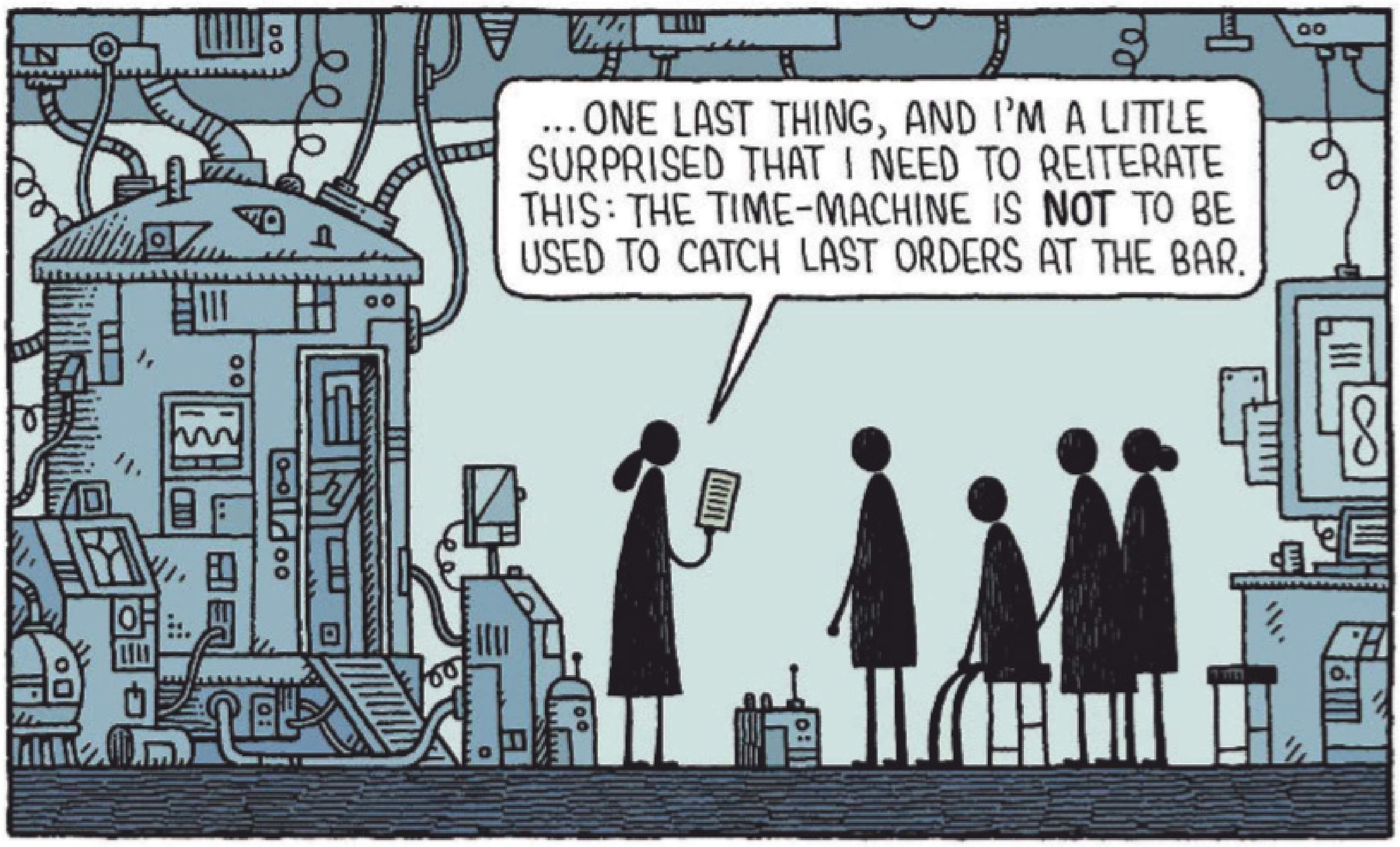
13 July, p 32

From Alan Larman,
Congleton, Cheshire, UK

Your article on food advice was unintentionally very amusing. I have read *New Scientist* from cover to cover since your first issue and have followed the changing, often conflicting, advice on food and nutrition. Since leaving boarding school, I have lived by the advice that "a little of what you fancy does you good, but too much of anything will kill you".

I have a very varied diet and love fruit, vegetables, fish and meat, but have only a small appetite. I recently turned 80, but I am often mistaken for 60 or even younger. Another good piece of advice, taken from an old song, is "I'll eat when I'm hungry, I'll drink when I'm dry... if whisky don't kill me, I'll live till I die."

I hope to be following *New Scientist* for many years yet – and enjoying my food.


...ONE LAST THING, AND I'M A LITTLE SURPRISED THAT I NEED TO REITERATE THIS: THE TIME-MACHINE IS **NOT** TO BE USED TO CATCH LAST ORDERS AT THE BAR.

TOM GAULD for NEW SCIENTIST

There are other reasons to prefer organic food

6 July, p 22

From Cathy Cook,
Lyndhurst, Hampshire, UK

James Wong considers organic food only from the viewpoint that it is said to be more nutritious. But probably the most important motivator for its consumers is to avoid the pesticide residues that industrially farmed fruit and vegetables typically contain. I don't know of there yet being a requirement anywhere to disclose the level of pesticides in food to shoppers, so the safest bet is to buy organic.

Another wider-reaching reason for buying organic food, which should be of interest to everyone whether they have a taste for pesticides or not, is that it supports traditional farming methods that have existed for millennia. As we face such a precarious future here on Earth, these methods must now be preserved at all costs for future humans to benefit from.

Organic farmers work with the soil to build and preserve its fertility, and thus increase its productivity. In contrast, industrial-scale, chemically assisted farming exploits the land relentlessly until the soil is depleted and the land eroded.

From Aroha Mahoney,
Te Awamutu, New Zealand

Wong describes many reasons why analysing the nutrient composition of organic and non-organic food is difficult to do. Surely a better way to look at an organic diet would be to compare the health outcomes in groups that are made up of those who primarily consume organic food and of those who don't?

I have rheumatoid arthritis and can report that when I eat a mainly organic diet of home-grown vegetables and organic meat and fish, my pain levels are lower and my energy levels are higher. It would be interesting to see if there is a measurable difference in things like diabetes or cardiac problems in these two groups.

Don't just plant trees, make things with them

20 July, p 20

From Butch Dalrymple Smith,
La Ciotat, France

Over and over, we hear that one of the solutions to global warming is to plant trees. Certainly, these magnificent means of pulling carbon dioxide out of the atmosphere are an essential part of our response to climate change.

But it is equally important to do something with the wood that is produced. Leaving trees to die, rot or burn returns the carbon to the atmosphere. If we build houses, furniture and boats out of wood, we not only lock all that carbon away for as long as the object exists, but also reduce the production of cement and plastics that have their own detrimental effects on the environment.

It is better to power electric vehicles with hydrogen

13 July, p 18

From Scott McNeil,
Banstead, Surrey, UK

Electric cars are in the news again. Over the past few years, I have become concerned that people often treat battery-powered electric vehicles as a panacea. I see many problems with this.

If demand for cobalt, nickel and lithium for batteries can be met, it will cause environmental damage in places such as China, Bolivia and the Democratic Republic of the Congo. I have always suspected that the environmental cost of producing such batteries has been glossed over.

A report for Volkswagen earlier this year did try to address this. Electric vehicles should be more environmentally friendly in the long run. But the report showed that manufacturing an electric car emits twice as much carbon dioxide as its diesel counterpart. It seems that the majority of that difference is due to the manufacture of the battery. And the issue of recycling is also yet to be fully addressed.

So I was delighted to see you discuss the potential benefits of hydrogen power (8 June, p 20). Hydrogen fuel cells are a proven technology which, unlike batteries, last for the life of the vehicle and extra energy isn't consumed to carry a heavy battery.

What on Earth would be the cost of a Mars mission?

15 June, p 38

From Hilary Gullen,
East Molesey, Surrey, UK

I read Leah Crane's article on missions to Mars with great interest. But we hear little about the potential impact of rocket launches on the climate. Astronauts frequently remind us of the fragility of the atmosphere, but is sending them to space causing the damage they warn of?

Turning the space station into a business has a price

15 June, p 5

From Ben Haller,
Ithaca, New York, US

So NASA has decided to create a "commercial destination" on the International Space Station where tourists could stay in the future, with the aim of facilitating for-profit space tourism. That sounds fun: who wouldn't love to see Earth from orbit and experience weightlessness?

But the problem is that space tourism is projected to have a huge environmental impact. A thousand suborbital trips per year – peanuts compared with what NASA's plans might lead to – could result in warming of up to 1°C at Earth's poles during winter (30 October 2010, p 5). Should we subsidise another way for the irresponsible rich to accelerate the destruction of our planet? Must we actively dig our own graves?

Defeating ransomware would be easy, if only…

13 July, p 9

From Hillary J. Shaw,
Newport, Shropshire, UK

Chris Stokel-Walker reports that ransomware attacks are on the rise. Surely these can almost always be defeated by backing up all data securely to a computer that has no internet access? Can't we design software that will do this automatically, as often as every 5 minutes if necessary? Its users would only lose data changed since the last backup. The sole expense would be that of a quarantined backup computer and the power to run it. That has to be cheaper than a bitcoin ransom.

I believe I'll have another drink, or maybe not

Letters, 6 July

From Peter Basford,
Potters Bar, Hertfordshire, UK

Guy Cox suggests that the inability to make a decision proves free will exists. A deterministic decision-making process can find the weights of multiple options to be equal and so be unable to decide. It doesn't follow that because I can't decide whether to have an extra pint before I go home, therefore I must have free will.

Cash isn't the only driver for returning a wallet

29 June, p 17

From Chris Brausch,
Thames, New Zealand

It seems that lost wallets with more money inside are more likely to be returned than those with smaller sums. Someone who finds one will probably consider the amount of trouble they would have to go to in order to return it compared with the benefit to the person who lost it.

Personally, I would think twice about returning a wallet with only a few dollars in it. But if it had a credit card and driver's licence in it, that surely would be the real driver for returning it.

Lions in trees are more common than we think

6 July, p 26

From John Clark, Leeds, UK

You present a photograph of lions climbing trees in Lake Nakuru National Park in Kenya's Great Rift Valley and say that this is a relatively rare behaviour. I photographed lions doing this in Solio Ranch, Kenya, in 1995.

The editor writes:

This could be as a result of local pressures and limited to certain lion groups. A study in Tanzania's Lake Manyara National Park found that lions climbed trees to avoid buffalo and elephants, but this behaviour was observed less often in the Serengeti National Park, even though the same types of trees are there.

The metric system is not in fact a French plot

Feedback, 22 June

From Keith Atkin, Sheffield, UK

Allow me to express my support for Feedback's comments on the metric system. But though it was certainly developed in France, its roots lie with English bishop John Wilkins, who proposed a decimal system of measurement in 1668.

Please tell us the worst on methane emissions

2 March, p 10

From Chris Eve, Lynton, Devon, UK

Michael Le Page reports that climate models may have missed major effects from clouds. Two more effects, which James Lovelock described in *The Revenge of Gaia*, are the effects of methane emitted from melting tundra and from underwater methane hydrate. Then there are the fires in Arctic forests and peat (see page 28)

I hope that someone will give us worst-case estimates for how high mean global temperatures could rise if those methane stores are substantially released, and for the lowest temperatures at which such mobilisation could be triggered.

Of course, there will be huge uncertainties in these numbers because, for example, estimates of the quantity of methane hydrate vary by an order of magnitude. But having worst-case estimates could provoke research aimed at reducing uncertainty.

Want to get in touch?

Send letters to New Scientist, 25 Bedford Street, London WC2E 9ES or letters@newscientist.com; see terms at newscientist.com/letters

Do we already know why cat owners are bolder?

6 July, p 43

From Anne Sproule,
Ottawa, Canada

I wonder why Ruth Searle writes of surprise that cat owners were found to be more adventurous and unconventional than dog people. Just last year, you reported that many cat owners are infected with *Toxoplasma gondii*, a parasite carried by cats that makes infected animals, including humans, more prone to risky behaviour (4 August 2018, p 17).

We haven't actually seen intelligent glass yet

13 July, p 7

From Eric Kvaalen,
Les Essarts-le-Roi, France

Donna Lu reports that researchers have created a glass artificial intelligence. But their paper says only that they did computer simulations of what would happen to light inside such material.

They modified the distribution of areas with different indices of refraction in the simulation until they got the simulated material to behave in the way they wanted.

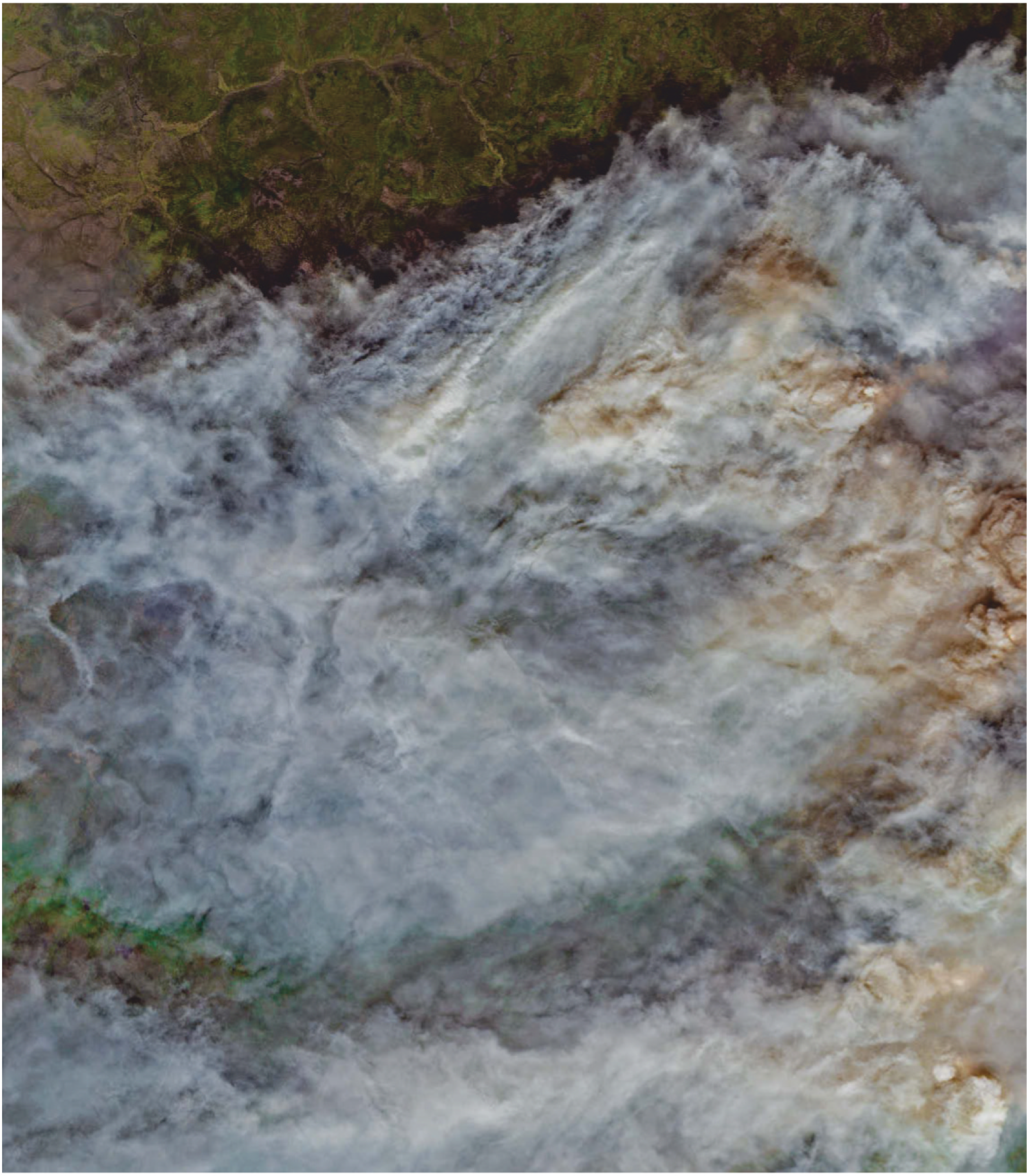
The editor writes:

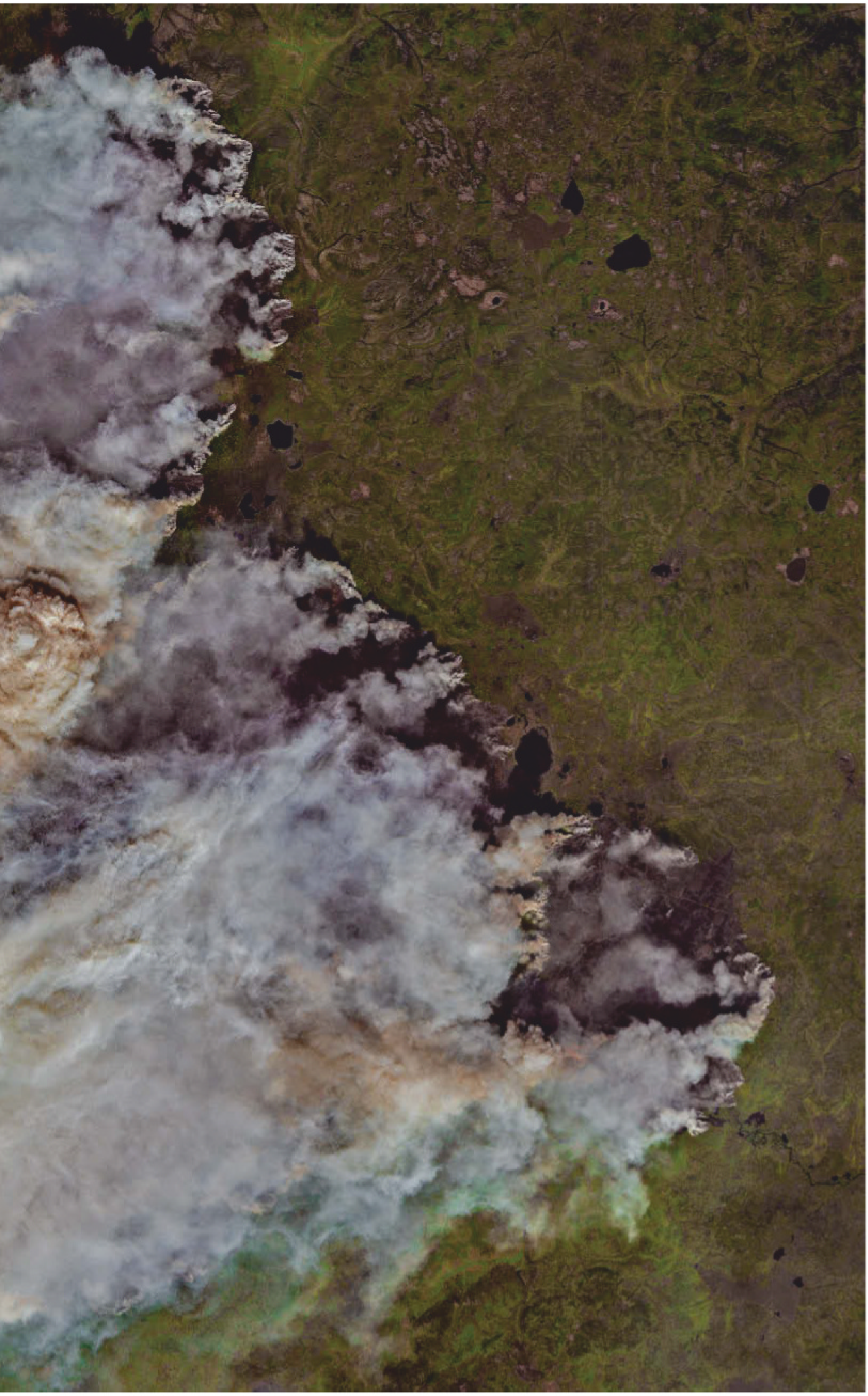
The researchers respond that in the field of optics and AI, the computer model is considered to be an extremely high fidelity reproduction of the real thing. They do have plans to put the results into a physical object.

For the record

Cold facts: An Arctic fox travelled 3506 kilometres during a 76-day polar marathon (6 July, p 16).

We're shaken: The epicentre of an earthquake is on Earth's surface above its focus (13 July, p 7).





Arctic on fire

Image Contains modified Copernicus Sentinel data [2019] Sentinel Hub/Pierre Markuse

HUGE wildfires are continuing to burn across the Arctic, releasing more carbon dioxide in 2019 than in any year since satellite records began nearly two decades ago.

The ones pictured here in northern Russia show a burn scar about 550 square kilometres in size and enormous smoke plumes. The fires' hotspots – in yellow, orange and red – were detected using shortwave infrared sensors on the EU's Sentinel-2 satellite.

Temperatures have been well above average in the region and fires erupted in boreal peatlands across Siberia early in June. Normally the fires would last a few days, but this year, some have been ablaze for a month and a half.

The result is the rapid release of over 121 megatonnes of carbon dioxide – more than Belgium's emissions in 2017 – eclipsing the previous record of 110 megatonnes of CO_2 for the whole of 2004. The Arctic wildfire season runs from July to August, so the burning could continue for several more weeks.

While the fires were initially clustered around the north of the Sakha Republic in Russia, more fires have appeared elsewhere in the country, along with Alaska and Greenland. Ruth Mottram at the Danish Meteorological Institute says the whole of Greenland has been experiencing "something exceptional" in high ground temperatures, which may be a contributing factor to fires, along with low rainfall.

"These Arctic fires are expected to occur more severely and more frequently in the future," says Merritt Turetsky at the University of Guelph, Canada. ▮

Adam Vaughan

A world gone bad

Utopian solutions and brutally realistic analyses reveal the same picture: the global economy is broken and needs fixing, finds **Joanna Kavenna**

Books

Not Working: Where have all the good jobs gone?
David G. Blanchflower
Princeton University Press

Fully Automated Luxury Communism: A manifesto
Aaron Bastani
Verso

Measuring Poverty Around the World
Anthony B. Atkinson
Princeton University Press

IN 2016, the UK voted to leave the European Union. Since then, the country has been in crisis. Talk has been of virtually nothing else. Then there is the talk about the talk. "To say the present era is one of crisis borders on cliché," writes Aaron Bastani in his polemical manifesto *Fully Automated Luxury Communism*.

What else could he say, given the situation? This grim picture is expanded on in two more books. In *Measuring Poverty Around the World*, Anthony Atkinson wrestles with the fact that even as countries become wealthier, poverty remains entrenched. And David Blanchflower's central theme is the crisis of underemployment and underpayment, yet his title *Not Working* expresses a more general failure of the global economy as well.

Since the end of the cold war, Atkinson writes, "the attitude of Western democracies has been that their view of the world's political organisations has triumphed". Bastani calls this "capitalist realism" – the idea that capitalism is the only plausible system – and cites political scientist Francis Fukuyama's influential argument about reaching the end of history. Yet, in 2008, history returned.

As Blanchflower puts it, "something horrible happened". All three authors agree that the current malaise derives from the financial crisis of 2007-8, and the cataclysmic mishandling of its aftermath by those in power.

Blanchflower was among those who were tasked with handling the crisis. He was serving on the Bank of England's Monetary Policy Committee and told everyone that austerity would make things worse. Nobody listened.

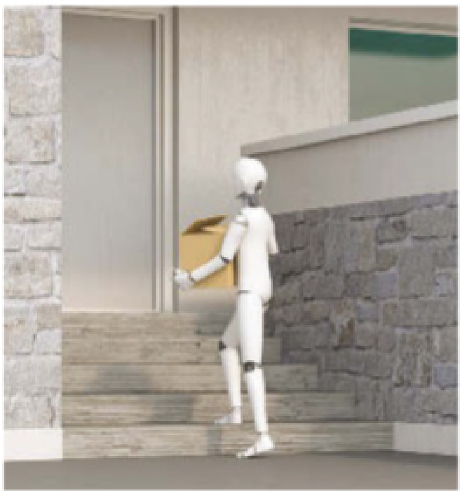
Instead, George Osborne, then the UK's chancellor of the exchequer, "a reverse Robin Hood", seized a "unique political opportunity… to reduce the size of the state and never mind the social and economic consequences". Internationally, a perverse illogic prevailed, as US talk show host Stephen Colbert pointed out at the time: "We have to keep cutting government budgets and laying off people until those people get jobs."

More than a decade on, people are still hurting. They often can't find employment, or the scant work they can find offers little security or pay. They have no prospect that their living conditions will be ameliorated. Rightly, many of these people blame the "learneds" who failed to predict the crash. For example, a limo driver told Blanchflower that people voted Brexit because "ordinary people had no hope". How can we have hope when policy-makers haven't learned from their mistakes?

Worse, as Blanchflower says, these policy-makers "now have little firepower to deal with the onset of the next economic crisis". If you are already despondent about the situation, I guarantee this book will make you feel worse.

JULIE DERMANSKY/POLARIS/EYEVINE

The global crash closed many businesses in New York (above). Future robot deliveries (below) will bring further challenges to the workforce



WESTEND61/GETTY

Atkinson, too, refused to sugar-coat his subject. Sadly, he died before finishing this book, but it has been brought to publication, at his request, by his colleagues John Micklewright and Andrea Brandolini. With its unfinished chapters explored in afterwords by economists François Bourguignon and Nicholas Stern, it is at the very least a worthy successor to Atkinson's 2015 study *Inequality: What can be done?*

Atkinson became an economist in the 1960s after working with deprived children in Hamburg, Germany, and published major works, beginning with *The Economics of Inequality* in 1975.

Five decades on, says Atkinson, poverty remains "one of the two great challenges facing the world as a whole today, along with climate

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change, with whose consequences poverty is intimately connected".

Atkinson considers various definitions of poverty, but his fundamental argument is that the free movement of capital, combined with governments' failure to regulate and tax multinationals, has led to the loss of employment and to insecurity among workers and their families in many countries.

He agrees with Blanchflower and Bastani that this is a failure of the learneds: "Our governments have lost sight of their obligation to act on behalf of all their citizens; they have allowed them to become subservient to economic forces." And he argues that "we need to return to a situation where 'the economy' is a means of fulfilling the life hopes and ambitions of people, not vice versa". Wise words, but is anyone able to listen?

Atkinson and Blanchflower find that people want to work to earn money, and that having decent, fulfilling jobs makes people happier. Bastani argues that people would be even happier if they didn't work at all. He proposes that we need to move from crisis to utopia – to "a world beyond jobs, profit and even scarcity". This is the "fully automated luxury communism" of his title.

> **"How can we have hope about the future when policy-makers haven't learned from their mistakes?"**

Bastani evokes Karl Marx's idea that automation will create "a society in which work is eliminated, scarcity replaced by abundance and where labour and leisure blend into one another". Robots will do physical tasks such as driving and delivering things. We will "mine the sky" thanks to Elon Musk's innovations in conquering the final frontier. Life expectancy will be enhanced by gene therapies. Our expanding population will be fed by cultured meat. The new populism will be "luxury populism": socialist and environmentally aware.

In Bastani's view, Marx was let down by the technological insufficiencies of every era prior to ours; this is the first time our technology has been sufficient to give rise to a post-scarcity economy, if we want it, and a realm of plenty "beyond imagination".

What Bastani doesn't quite imagine, however, is a world in which people might actually enjoy their work. Where in Bastani's utopia is the place for someone whose version of socialism is more William Morris than Karl Marx, someone who values work as an end in itself?

Like Blanchflower and Atkinson, Bastani identifies elite learneds as the source of our ills. And for his luxury communism to work, these elites have to agree not to pocket the trillions they stand to make but, instead, to share the profits.

What happens if Musk doesn't "want it"? Maybe he is happy with the way things are. Regardless, there will be no storming of the Winter Palace in Bastani's utopia, because, he writes, his politics "recognises the centrality of human rights, most importantly the right of personal happiness".

Bastani's future is interesting: "a figurehead of possibility forged for a world changing so rapidly that new utopias are needed – because the old ones no longer make sense". It is a dream to replace the bankrupt capitalist dream, and to counter the dark fantasies of non-luxury populists.

These authors understand that there has been a lot of talk already. They believe we need better talk. They are all highly intelligent people who are trying to understand why the situation in which we find ourselves is so stupid. Their books all have virtues, but if you can only face one, then, for *mea culpas* and an honest if demoralising insider view, read Blanchflower. For devastating statistical analysis, read Atkinson. For riotous techno-optimism, read Bastani.

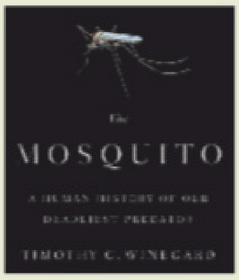
It is a wonder Bastani missed the opportunity to call his theory Totally Automated Luxury Communism, or TALC. TALC, which we could liberally sprinkle across our broken world. TALC to mitigate all the TALK. ▮

Joanna Kavenna's new novel *Zed* is published by Faber & Faber

Don't miss

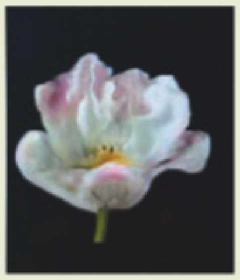
Listen

Chris Stringer's research is one big reason why we think humans originated in Africa. Hear him in conversation with the *Financial Times*'s science editor Clive Cookson at The Royal Institution in London on 5 August at 7 pm BST.



Read

The Mosquito: A human history of our deadliest predator by Timothy C. Winegard (Dutton) reveals how a small and insubstantial insect triggered the rise and fall of empires, and killed nearly half of humanity in the process.



Last chance

Entangled Realities at the House of Electronic Arts Basel, Switzerland, is a group exhibition exploring the social and personal challenges of artificial intelligence. Can human and robot minds coexist? If so, at what cost? Ends 11 August.

TOP: GERBIL; BOTTOM: ANNA RIDLER, DETAIL OF BLOEMENVEILING AUCTION, 201

The science fiction column

Reflections of a broken world

Destabilised times breed very different responses in two new sci-fi stories: one a thriller about profiting from nihilism, the other a classic space dilemma – but with human values to the fore, writes **Helen Marshall**

Helen Marshall is an editor, award-winning writer and senior lecturer at the University of Queensland, Australia. Follow her on Twitter @manuscriptgal

Books

Empty Hearts

Juli Zeh (trans. John Cullen)
Penguin Random House

To Be Taught, If Fortunate

Becky Chambers
Hodder & Stoughton

Helen also recommends…

Books

The Memory Police

Yoko Ogawa (Trans. Stephen Snyder)
Harvill Secker
A poetic exploration of the effects of state surveillance.

Episodes

Christopher Priest
Gollancz
Eleven short stories by one of sci-fi's most absorbing and provocative writers.

THOMAS DWORZAK/MAGNUM PHOTOS

A string of novels this year explore the destabilised Western political psyche

WHAT would you do if you could push a little red button to erase everyone you don't agree with politically? *Empty Hearts* by Juli Zeh is set several years in the future in a Germany where the political shocks of Trump and Brexit, exacerbated by a second financial crisis and the growth of an ultrapopulist movement, have undermined the will towards democracy. Given a choice between owning a washing machine or the right to vote, most people would choose the appliance.

Disillusioned but sheltered from the fallout of these crises, the novel's anti-hero, Britta, has found a way to profit from nihilism by cornering the market in domestic terrorism. She runs The Bridge, a legal organisation that identifies the suicidally inclined, and, should they prove untreatable, pairs them with terrorist organisations such as Islamic State, for which they carry out suicide attacks. But now a rival organisation, Empty Hearts, led by a rejected client, threatens Britta's market domination.

This year has seen a string of novels exploring the destabilised Western political psyche, but *Empty Hearts* strikes me as one of the strongest so far. It asks, what if the current political climate led not to catastrophe, but to stagnation? Its answer is a riveting thriller and a nuanced piece of social science fiction.

The novel's only weakness is that its tight focus on social developments assumes stability in areas such as tech advances and, most strikingly, climate change, which is relegated to one more ideological battleground. On the whole, though, it is nuanced and brilliantly executed – a standout.

"Given a choice between owning a washing machine or the right to vote, most would choose the appliance"

To Be Taught, If Fortunate by Becky Chambers seems spawned from similar concerns: overexposure to a frantic news cycle, loss of political efficacy, a feeling of rootlessness. But this novella – set in her bestselling *Wayfarers* world – has a very different take. It is the turn of the 22nd century and Ariadne O'Neill is part of a crew on an interstellar mission to survey habitable exoplanets. Their journey takes them 15 light years from home, a distance that only allows them to maintain intermittent contact through news packages and updated mission briefings.

Caught up in the joys and trials of their expedition, they begin to disconnect from the increasingly volatile political situation at home – until they lose contact altogether. With fuel enough for a return to the planet that launched them or a further foray into the unknown, the crew must decide what they owe to those left behind.

Whereas Zeh risks turning news-weary readers into trolls unmoored from their compassionate instincts, Chambers seems to suggest going offline, tuning out the noise and refocusing on what you value most. In this love letter to science, she weaves together descriptions of technology with entertaining characters and a fast-moving, emotional plot. Her future is fraught with difficulties, but a focus on warmth, camaraderie and teamwork is welcome.

At times, her book wears its heart too much on its sleeve. Chambers names the exoplanets Mirabilis, Opera and Votum (Latin for miraculous, work and prayer), which risks giving the novella the flavour of a spacefaring *Eat, Pray, Love*. But this may be unfair. The effect is magnified, I suspect, by the lack of similarly optimistic novels published right now. As bleakness becomes a stand-in for realism, *To Be Taught, If Fortunate* is still a breath of fresh air. ▮

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Do we see reality?

The idea that our perception matches reality is intuitive – but it may be blinding us to deeper truths, says cognitive scientist
Donald Hoffman

LIFE insurance is a bet on objective reality – a bet that something exists, even if I cease to. This bet seems quite safe to most of us. Life insurance is, accordingly, a lucrative business.

While we are alive and paying premiums, our conscious experiences constitute a different kind of reality, a subjective reality. My experience of a pounding migraine is certainly real to me, but it wouldn't exist if I didn't. My visual experience of a red cherry fades to an experience of grey when I shut my eyes. Objective reality, I presume, doesn't likewise fade to grey.

What is the relationship between the world out there and my internal experience of it – between objective and subjective reality? If I'm sober, and don't suspect a prank, I'm inclined to believe that when I see a cherry, there is a real cherry whose shape and colour match my experience, and which continues to exist when I look away.

This assumption is central to how we think about ourselves and the world. But is it valid? Experiments my collaborators and I have performed to test the form of sensory perception that evolution has given us suggest a startling conclusion: it isn't. It leads to a crazy-sounding conclusion, that we may all be gripped by a collective delusion about the nature of the material world. If that is correct, it could have ramifications across the breadth of science – from how consciousness arises to the nature of quantum weirdness to the shape of a future "theory of everything". Reality may never seem the same again.

The idea that what we perceive might differ from objective reality dates back millennia. Ancient Greek philosopher Plato proposed that we are like prisoners shackled in a fire-lit cave. The action of reality is happening out of sight behind us, and we see only a flickering shadow of it projected onto the cave wall.

Modern science largely abandoned such speculation. For centuries, we have made stunning progress by assuming that physical objects, and the space and time in which they move, are objectively real. This assumption underlies scientific theories from Newtonian mechanics to Albert Einstein's relativity to Charles Darwin's theory of evolution by natural selection.

Natural selection, you might think, gives a simple reason why our senses must get it largely right about objective reality. Those of our predecessors who saw more accurately were more successful at performing essential tasks necessary for survival, such as feeding, fighting, fleeing and mating. They were more likely to pass on their genes, which coded for more accurate perceptions. Evolution will naturally select for senses that give us a truer view of the world. As the evolutionary theorist Robert Trivers puts it: "Our sense organs have evolved to give us a marvellously detailed and accurate view of the outside world."

> **"For centuries we have made stunning progress by assuming things are real"**

The truth of such statements can be tested with mathematical rigour using the tools of evolutionary game theory, introduced in the 1970s by John Maynard Smith. In this theory, different strategies for coping with the natural world can be set against each other in simulations to see which approaches are fitter – in the sense of producing more offspring.

In the case of perception, we can study how "truth" strategies, which see objective reality as it is, fare against "pay-off" strategies, which see only survival value. Take oxygen. Too much or too little oxygen in the air kills us; a narrow range keeps us alive. Now imagine living in an environment where the level of oxygen varies considerably, and you have to make survival judgements about whether to venture outside.

For the sake of this example, the amount of oxygen in the air is taken to be an objective truth. You might imagine seeing it on a colour scale from red for low to green for high. That's the truth strategy: you know the truth, but you don't know if you'll die. A pay-off strategy would mean seeing red colours for levels of oxygen that kill you, and green for those that don't. You see what you need to survive, but don't see the objective truth of how much oxygen there is.

›

MARINA LOEB

Our senses tell us only what we need to know to survive

PLAINPICTURE/RUDI SEBASTIAN

The objective truth I started seeing a decade ago, in simulations conducted together with my graduate students Justin Mark and Brian Marion at the University of California, Irvine, is that evolution ruthlessly selects against truth strategies and for pay-off strategies. An organism that sees objective reality is always less fit than an organism of equal complexity that sees fitness pay-offs. Seeing objective reality will make you extinct.

If this seems hard to swallow, suppose you are writing a novel on a laptop, and the novel's icon on the desktop is green, rectangular and in the centre of the screen. Does this mean that the novel itself is green, rectangular and in the centre of your laptop?

Of course not. The desktop interface is there to mask a complex reality of software, circuits and digital 1s and 0s to provide a simple way to interact with it. If you actually had to flip computer bits to write a novel, you would switch to pen and paper.

Reality is virtual

That, evolutionary game theory predicts, is what evolution has done for us. Natural selection has given us sensory systems that are a simplifying user interface for the complexity of the world. Space, as we perceive it around us, is a 3D computer desktop, with tables, chairs, the moon and mountains icons within it.

In other words, our senses constitute a virtual reality. If you play the video game *Grand Theft Auto* with a virtual-reality add-on, you see a 3D world with 3D objects, such as a black steering wheel in front of you. If you turn your head, however, the steering wheel disappears. Indeed, it ceases to exist, because it only exists when we are looking where it should be in the simulation. The reality that exists – circuits and software again – is utterly unlike a steering wheel. But it prompts you to create a steering wheel when it is needed, and to destroy it when it isn't.

In like manner, we create an apple when we look, and destroy it when we look away. Something exists when we don't look, but it isn't an apple, and is probably nothing like an apple. The human perception of an apple is a data structure that indicates something edible (a fitness pay-off) and how to eat it. We create these data structures with a glance, and erase them with a blink. Physical objects, and indeed the space and time they exist in, are evolution's way of presenting fitness pay-offs in a compact and usable form.

But hang on, drop the apple. A lion on the African savannah isn't just an icon in your interface. It has agency, and can kill you, so it must be objectively real.

I wouldn't mess with a lion, for the same reason I wouldn't carelessly drag the green icon of my novel to the virtual recycle bin. Not because I take that icon literally, and think the novel is green and rectangular. But I do take that icon seriously: if I drag it to the bin, I could lose all my work.

The objection that a lion must be objectively real because anyone who looks over there sees a lion that we can all agree looks like a lion – so it isn't unique to our subjective experience – isn't a valid one, either. Humans agree about what we see because we have all evolved a similar interface. The interfaces of some other species, such as prey mammals, may have icons for lions that are similar to ours, and that guide actions similar to ours, such as keeping far away from them.

That leaves the fact that treating our observed, subjective reality as objective reality has allowed us to create scientific theories – frameworks that allow us to make predictions about how the world works, and so are presumably part of an objective reality that exists outside our heads. But here too there are hints from deep within science itself that perception and reality don't match.

Quantum theory is our best physical theory of fundamental reality. But with its counter-intuitive effects of "spooky action at a distance" and the perennial mystery of the dead-yet-alive Schrödinger's cat, it drives a coach and horses through cherished ideas from our classical realm of experience: that objects have definite values of the properties pertaining to them, that those properties don't depend on how they are observed, and that influences propagate no faster than light.

This is jolting if we assume that objects and their measurable properties are part of an objective reality. But it is no surprise if we think of objects and their properties as data structures created as needed to represent fitness pay-offs. In this case, the values of properties will depend on when and how we create them.

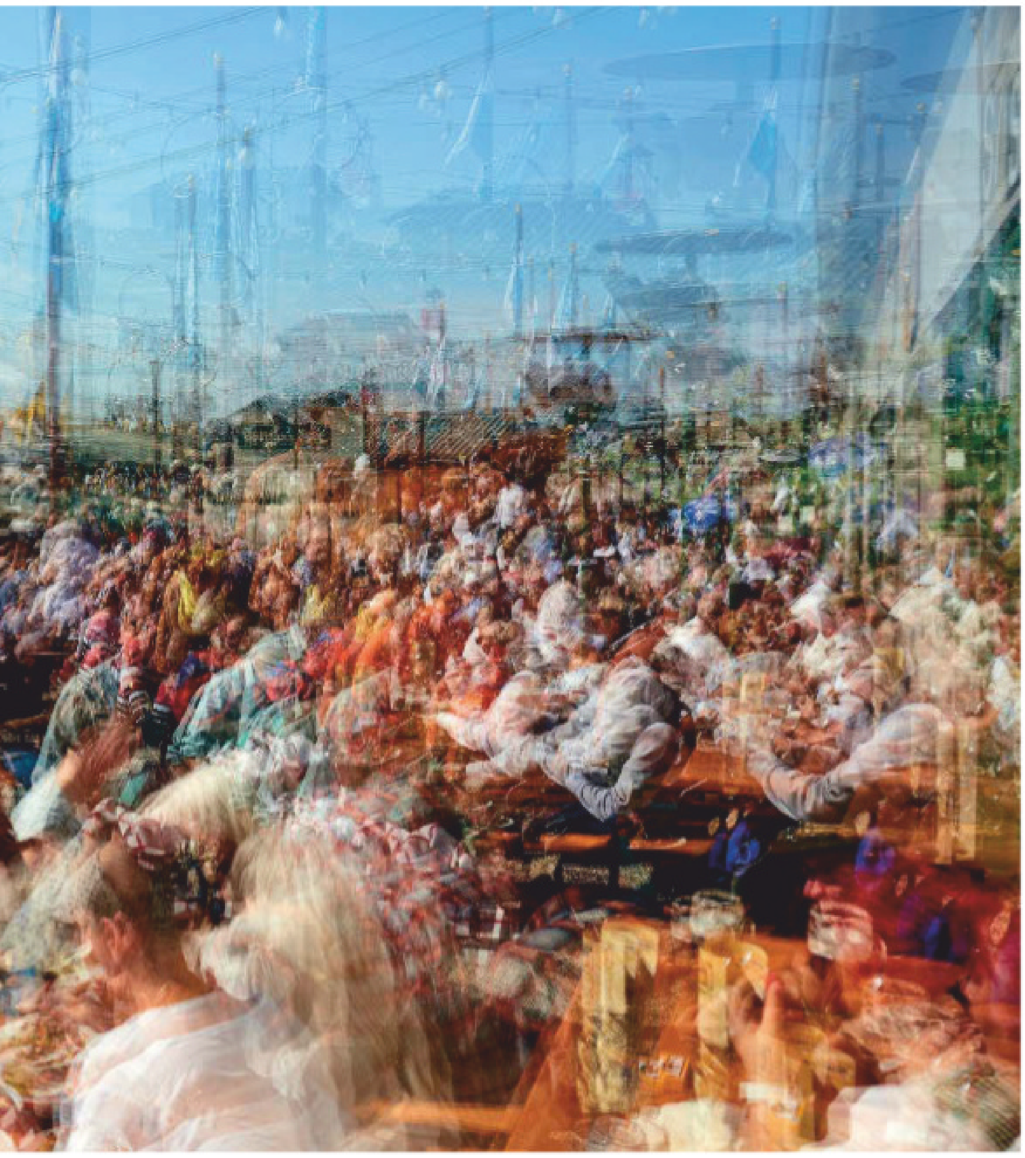
This approach aligns with the quantum-Bayesian interpretation of quantum theory, or QBism, in which the uncertainty inherent in quantum observations is all in the minds of the observers. As three pioneers of QBism, Christopher Fuchs, David Mermin and Rüdiger Schack have put it, "A measurement does not, as the term unfortunately suggests, reveal a pre-existing state of affairs. It is an action on the world by an agent that results in the creation of an outcome – a new experience for that agent. 'Intervention' might be a better term."

If our team's evolutionary ideas are true, that might lend momentum to models of quantum theory that see quantum states, and the mathematical and interpretational structures around them, as "epistemic" – reflecting not necessarily reality, but just our state of knowledge of it.

But it goes further. Even perceptions as seemingly fundamental as space and time might not actually be part of objective reality. That insight could inform our search for theories that unite the two great theories at the heart of modern physics.

For decades, we have tried and failed to reconcile quantum theory with general relativity, Einstein's theory of gravity that

> **"Even perceptions as fundamental as space and time might not be part of objective reality"**



Donald Hoffman is a professor of cognitive sciences at the University of California, Irvine. His research interests span visual perception, artificial intelligence, evolutionary psychology and the hard problem of consciousness. His book on human perception, *The Case Against Reality,* is published this month.

dictates how the universe works on large scales. At a very basic level, these theories fail to agree on the nature of space and time.

General relativity demands that space-time, the four-dimensional structure that space and time together form, is smooth and continuous, whereas a quantum description requires a pixelated description. As the theoretical physicist Nima Arkani-Hamed has said: "Almost all of us believe that space-time doesn't exist, that space-time is doomed, and has to be replaced by some more primitive building blocks." Admittedly, no one yet knows what those might be – but our insights suggest the hunch they must be replaced is right.

It isn't just in physics where we may need to overhaul our ideas about reality to make progress. Another is in solving the "hard problem" of consciousness. This problem of how and why our brains generate conscious experience remains intractable despite centuries of thought. As biologist Thomas Huxley put it in 1869: "How it is that anything so remarkable as a state of consciousness comes about as a result of irritating nervous tissue, is just as unaccountable as the appearance of the djinn, when Aladdin rubbed his lamp."

The brain-exciting technology of transcranial magnetic stimulation (TMS) illustrates how little progress we have made. Suppose we place a TMS unit near your scalp, on the right side of your head, near an area of the occipital cortex called V4. We turn on the device, and its strong and focused magnetic fields inhibit neural activity nearby. All colour drains away from the left half of your visual world; you see only shades of grey. We turn off the device, and the colour seeps back in.

Chocolate and vanilla

Neuroscience has turned up hundreds of such correlations between patterns of neural activity and specific conscious experiences. Most attempts to explain these correlations assume that the neural activity causes, or somehow gives rise to them. But how, precisely? What neural activity causes the taste of vanilla, and why doesn't it cause the taste of chocolate? In a network of interacting neurons, how exactly do changes in voltage, or in the flow of sodium, potassium and calcium ions through pores in neural membranes, create an individual conscious experience?

There are no theories, and few plausible ideas. But if we are trying to find the answer to the problem of conscious experience in the firing of neurons in space and time, when those neurons themselves are just icons in a subjective interface, perhaps that is no wonder.

So how can we break through our subjective perception and find objective reality? I don't know. But my collaborators and I are currently trying to solve the hard problem of consciousness by building a theory in which the underlying reality emerges from a vast network of interacting conscious agents and their experiences. Our space-time interface – together with shapes, colours and other sensory properties – is as a visualisation tool that some agents, like us, use to simplify and interact with this network.

Our hypothesis, of course, is probably wrong. But the point of science is to be precise, so we can find out precisely what is wrong with the idea. Our theory of interacting conscious agents fails if its predictions don't square with well-tested results of classical physics, quantum theory, general relativity, evolution by natural selection and so on in our space-time interface.

And the argument turns on itself. We used the theory of evolution by natural selection to discover that what we perceive isn't objective reality, but an interface with it. Now we realise that evolution itself may be just an interface projection of deeper dynamics stemming from a network of conscious agents. The goal ahead is to work out those dynamics in detail, and figure out how, precisely, they map onto our space-time interface. This will allow us to make empirical predictions testable by experiments within our subjective reality.

Science so far has focused its search on this immediate reality. What it has found can guide our theories and test our predictions as we try to look beyond it, to find the nature of objective reality. Can we do it? Just like I take out life insurance, I'm betting we can. ▮

Water from air

With a water crisis bearing down on us, incredible materials that can suck water from even arid desert air could quench our thirst, says **Nic Fleming**

THREE MEN in safety goggles stare intently at a clear plastic box filling gradually with fog. Droplets begin to form on the walls. They swell and eventually begin to trickle into the base of the fish tank-like container, forming small puddles. Omar Yaghi smiles broadly and congratulates his colleagues.

This seemingly prosaic moment in a laboratory at the University of California, Berkeley, may go down in history as the moment scientists turned the tide against water shortage. “Seeing those water droplets was one of the most amazing experiences of my life,” says Yaghi. “It meant I could create water where there is no water.”

That was a couple of years ago. Yaghi is now moving beyond drops and puddles, and breaking out of the lab. In his most recent trials, he sucked significant amounts of water from even arid desert-like air. The secret to it all? A sprinkling of extraordinary synthetic crystals based on a form of chemistry he helped pioneer two decades ago.

The potential implications are dramatic. The United Nations says the number of people living in areas of absolute water scarcity, where available supplies are insufficient to meet demand, will rise from 1.2 billion in 2014 to 1.8 billion in 2025. Even places with money to spend on reservoirs, water recycling and technologies like desalination are vulnerable to greater risks of drought as global temperatures and populations rise. Last year, for example, Cape Town in South Africa narrowly avoided “day zero”, the point at which water runs so low that residents are put on survival rations.

Yaghi knows all about water shortage. He was born in Jordan in 1965, the sixth of

JEREMY HORNER/PANOS

10 children. His parents Mwannes and Sadika were Palestinians who fled the fighting following the establishment of the state of Israel in 1948. He lived in one room with his brothers and sisters, and the family's cattle, in a home without electricity. Water was piped in for a few hours each week, and Yaghi sometimes had to get up at dawn to open a valve to ensure it reached their tank. "You had to think about every drop," he says. " Water was absolutely precious."

Mwannes sold the gold jewellery he had given Sadika as a wedding gift and used the proceeds to set up a butcher's shop. This paid for Yaghi to attend a private Christian missionary school, where his love of chemistry was sparked at the age of 10 when, one lunchtime, he sneaked into the library when it was supposed to be closed. There, in a book, he saw strange diagrams of different sized balls connected by sticks, which he later learned were molecular models. Yaghi sensed he was looking at a template for everything around him, that he had encountered some hidden truth. And the feeling was heightened by his being somewhere he wasn't supposed to be. "It was like meeting a secret love," he says.

> **"Even wealthy places will be vulnerable to drought as the planet's temperature keeps rising"**

When Yaghi was 15, his father sent him to join his older brother Khaled in the US, even though he spoke little English and didn't want to go. Yaghi arrived in New York, where he enrolled in a community college. He excelled and eventually became an assistant professor of chemistry at Arizona State University, where he set about finding new ways to link up those little balls and sticks to make previously unknown substances. Little did he know that they might one day help quench other people's thirst.

By this time, in the early 1990s, chemists › had made major strides in building organic compounds, which are based on carbon. However, when it came to constructing inorganic compounds, which are based mainly on any of the other elements across the periodic table, they had limited control over the products of their experiments. It was often a case of mixing chemicals in a flask and seeing what happened. Critics described the techniques used as "shake and bake", "mix and wait" and "heat and beat".

Among those seeking to move beyond this educated guesswork was the chemist Richard Robson at the University of Melbourne. From 1989, Robson gave the world new ways to design and make compounds called coordination polymers. These are extended arrays of atoms or ions, usually metals, linked together by longer molecules known as ligands. By changing the type of metal, Robson could change how many ligands would bind to it. A metal that bound two ligands might produce a string-like polymer, for instance. A metal that bound six ligands might produce a cubic lattice.

> **"This will improve access to clean water for millions of people"**

Soon, chemists had made a whole family of new materials, each with a different structure and properties. And because they could be made to remain in ordered, crystalline forms, they were easy to study. The only trouble was that Robson's polymers were liable to react with other substances, making them unstable and not immediately useful.

In the mid-1990s, Yaghi and his team began making coordination polymers consisting of negatively charged ligands joined not by single metal atoms but clusters of them. These materials, which he called metal organic frameworks (MOFs), had stronger bonds than previous coordination polymers, giving them greater stability.

He didn't have the field entirely to himself. Susumu Kitagawa at Kyoto University in Japan and Ian Williams at the Hong Kong University of Science and Technology also did early work on MOFs. But chemists across the world sat up and took note of Yaghi's work in 1999, when he reported the synthesis of MOF-5, a zinc-based polymer. It wasn't just that it was stable to an impressive 300°C. The incredible thing was

ERNESTO BENAVIDES/AFP/GETTY

Condensation stations

The village of Tojquia in the Cuchumatanes mountains of Guatemala is flanked by 35 towering nets, the largest about twice the size of a car parking space. Each net supplies villagers with up to 200 litres of freshwater a day. As the fog rolls over the high ground each morning, water droplets catch on the mesh, slide down, and then drip gradually into containers.

The Canadian charity FogQuest began exploring whether nets could provide water for the isolated community here 20 years ago. But this technique could be feasible in much less obviously foggy places. "I believe fog harvesting is quickly becoming viable in a wide variety of regions," says engineer Jonathan Boreyko at Virginia Tech.

The design of the nets matters. Too coarse and fog passes through, too fine and the water droplets don't slide down the net smoothly, clogging the strands. Boreyko and his colleague Brook Kennedy optimised the design, taking inspiration from the redwood trees of north California. They get a lot of their water from coastal fog, which condenses on their needle-like foliage and drips to the ground. Mimicking the parallel arrangement of the trees' needles, Boreyko and Kennedy's fog catcher design removes the cross fibres of traditional mesh nets to make "fog harps". A prototype installed on a farm in Virginia has produced three times as much water as traditional mesh designs.

This level of productivity could make fog capture attractive even in inland locations. A surprisingly large number of places get at least some fog in the mornings, and harps can be built big to increase their productivity. Boreyko cites interest from places as varied as the Mexican plains to the tropics of Bangladesh.

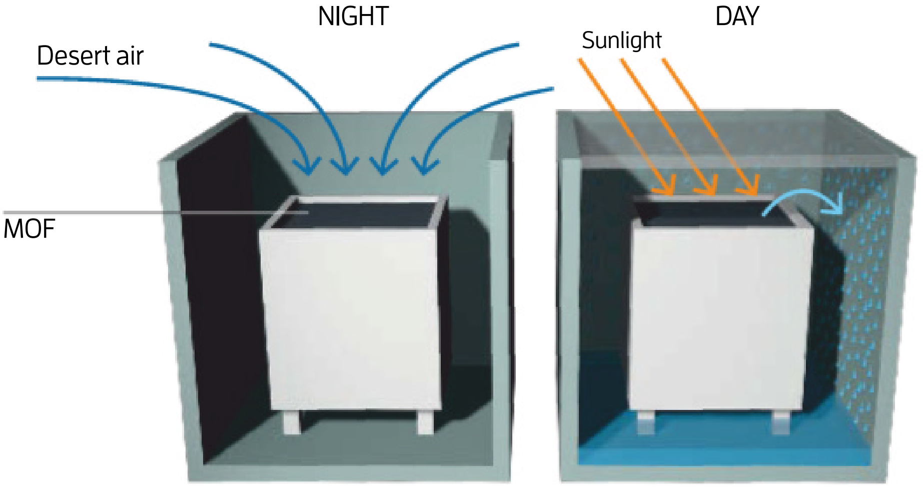
> Fog catching nets could be deployed in much less obviously foggy places than Guatemala

Even places with no fog have water vapour in the air that can be turned into a liquid with the right kit. Zero Mass Water, a company based in Arizona, promises to do this using large, solar-powered condensers it calls hydropanels. Two can draw around 10 litres of water per day from the air, even in arid climates, it says.

The problem the company faces is the energy required. It takes about 1.4 megajoules to produce a litre of water, roughly the same amount of energy required to boil the water for 40 cups of tea. On the other hand, the tech does away with the need for infrastructure to send water from place to place, which requires energy to install. This system is also readily scalable – to get more water, just add more panels.

You can even tap the water vapour emanating from your sweaty colleagues, if that appeals. Late last year, a company called Skywell launched the UK's first office water cooler that condenses water directly from the air. In future, the firm plans to sell an industrial unit big enough to serve a small town. Frank Swain

Box of tricks



At night, water vapour is sucked from cool air into a material called a metal organic framework (MOF) inside a plastic box

During the day, the case is sealed and heat from the sun warms the MOF, prompting the water to escape. It then condenses on the case and drips down to collect at the bottom

SOURCE: advances.sciencemag.org

that the gaps in this material gave it an internal surface area of 2900 square metres – nearly half a soccer pitch – per gram. Gas molecules accumulate and form thin films on surfaces. This means that, bizarre as it sounds, a canister containing MOF-5 can hold far more gas than an empty canister at the same pressure, thanks to the material's high surface area.

Their super sponge properties made MOFs look useful for a wide range of applications, such as storing carbon dioxide captured from power generators or gas to power cars. No wonder that at least 20,000 different MOFs have been made in the past 20 years.

These materials have been slow to fulfil their potential, however. The German chemicals giant BASF developed vehicles with natural gas tanks containing MOFs with Yaghi's help, anticipating greater demand for greener fuel. But a plan to launch them in 2015 was shelved because a crash in petrol prices skewered the economic rationale.

The first commercial applications for MOFs emerged in 2016, in the form of cylinders that store toxic gases used in the electronics industry and sachets to release a gas to block the effects of ethylene, a hormone released by fruit and vegetables that speeds ripening. But more widespread applications just haven't materialised.

The thing that could finally change this is the fact that MOFs aren't just good sponges, but extremely selective ones. MOFs have internal pores with specific sizes and shapes, making them ideal for taking up certain gases that fit those pores while excluding those that don't.

In 2013, Yaghi was studying how MOFs could separate carbon dioxide from water when he noticed one material that could rapidly take in water vapour, even in low humidity conditions, and then release it again when heated. "Immediately I thought, 'Wow, this could be used in the desert'," he says.

When Yaghi went on to survey the water-sucking capabilities of 20 different MOFs, he found one, based on zirconium and called MOF-801, that performed especially well. Its internal pores were the perfect size and shape to let water in and out. Yaghi then worked with engineer Evelyn Wang at Massachusetts Institute of Technology to develop a palm-sized water harvesting prototype, consisting of MOF-801 crystals pressed into a sheet of copper, encased in a plastic box.

Watching the box

To harvest water, the box is left open overnight, allowing the MOF to suck water molecules from the air into its pores. In the morning, the top is replaced and the sun warms the MOF and the water inside it. This prompts the water to be released and condense on the walls of the box (see diagram, above). In 2017, Yaghi's group found the device could harvest water from air of 20 per cent relative humidity, which is similar to the conditions in many deserts. They went on to make a larger device that produced the equivalent of 140 millilitres of water per kilogram of MOF per day in the lab. It was in this device that Yaghi saw those incredible drops of water through his safety goggles.

All this proved that the technology works. But will it really curb our worsening water shortage? There are other ways of extracting water from air, including by simple condensation. This isn't complicated: a cold surface will cool the air around it and force water vapour to form droplets. But it is power-hungry: think of a fridge with an open door. Even so, a few companies are already marketing devices that do this (see "Condensation stations", left).

Another problem with Yaghi's original devices is that they are based on zirconium. This metal may be resistant to corrosion and high temperatures, but it is expensive, at around $150 a kilogram. A cup of water produced by such a MOF is going to be pricey.

Yaghi, who recently set up a company called Water Harvesting Inc., knows he needs to think about economics as well as chemistry if his plans for a household appliance to help those at threat of water scarcity are to come to fruition. To that end, he has been testing MOF-303, which is based on aluminium, a much cheaper metal. In 2018, he reported devices based on this material could produce 230 millilitres of water per kilogram. He says he can boost that to more than 2 litres if he connects solar panels to the device and uses them to successively heat and cool it many times in 24 hours, rather than relying on day-night temperature cycles.

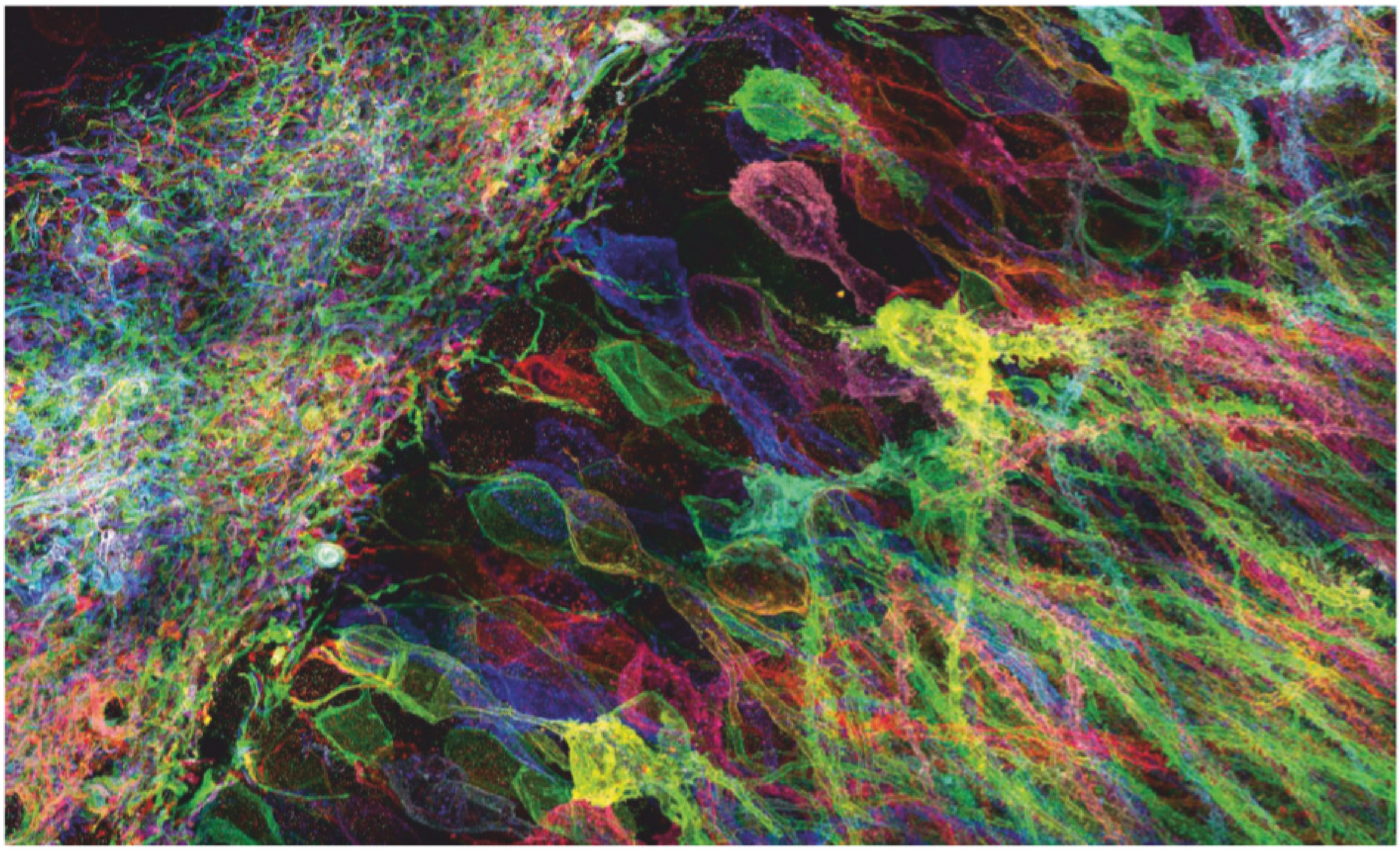
Might these refinements turn Yaghi's dream into a reality? Russell Morris at the University of St Andrews, UK, who is developing wound dressings and catheters containing MOFs to assist healing, says that is still uncertain. "There could be issues around how long the device will last, the build up of bacteria," he says. "It's hard to know whether it's feasible yet, but it's a neat idea."

Other leaders in the field think Yaghi isn't far from cracking it. "Capturing water from the air in places where there is little water is spectacular," says Omar Farha at Northwestern University in Illinois. "There will be challenges in scaling it up, but I don't see any showstoppers. I think this will successfully improve access to clean water for millions of people." If he is right, the day Yaghi watched droplets become drops, and drops become puddles, really will go down as a watershed moment. ▮

Nic Fleming is a writer based in Bristol, UK

Shedding light on the mind

Ed Boyden has pioneered three transformative technologies for studying the brain. He tells **Clare Wilson** how these will help us to discover what thoughts and feelings are really made of



FEI CHEN, DAWEN CAI, ED BOYDEN, MIT

THE brain is a complex network of some 86 billion neurons. To find out how they operate, we need to be able to record the activity of these cells. That is why the methods developed by neuroscientist Ed Boyden are so crucial. His breakthrough came in 2004 when, as a graduate student, he flashed a blue light at a nerve cell to see how it would react. Instantly, it fired. This was the birth of optogenetics, a technology that has revolutionised the study of brains and behaviour. We caught up with him to find out more.

What is the ultimate goal of your brain studies?
I have a deep desire to understand what it means to be human – the meaning of our thoughts and feelings. That is really what motivates me to get out of bed in the morning. This is something I have been obsessing about for many years, ever since I was a kid.

That is pretty ambitious. How will optogenetics help get us there?
Optogenetics involves putting new genes into brain cells to let us turn them on and off with light. Light has the unique advantage that you can really focus it down, even to individual cells. In 2017, along with Valentina Emiliani's group at the Vision Institute in Paris, we activated individual cells with 1-millisecond precision in an intact circuit in a slice of living brain tissue.

What else are you working on?
A technology that is the opposite of optogenetics in a way. Instead of sending light into the brain to trigger neurons to activate, or fire, we make neurons glow when they fire. This is called voltage imaging. It lets us watch the brain as it computes, with the precision of looking at individual brain cells.

Another of your technologies, expansion microscopy, is really different. It makes brain tissue physically bigger so you can see it better. What made you think of that?
I was brainstorming with one of my postdocs about the fact that in a neuron, all the molecules are jam-packed together. What if

Expanded brains

Brain circuitry can be visualised in unprecedented detail by using a swellable gel and fluorescent tags – techniques developed by Ed Boyden

you could separate them and make enough room to label them with visible molecules?

Almost as a joke, we started thinking maybe we should blow the brain up. Later, together with two fantastic graduate students in the lab, we started reading lots of papers on "swellable" polymers. We figured out a chemistry that worked.

We use basically the same kinds of polymers that you find in diapers, which absorb a lot of water. The idea is you inset the subunits of the polymer into the cells. Once in there, they form links and turn back into the diaper polymer. Then, when you add water, the polymer, and thus the brain, expands.

What have you discovered with the technique?
In 2019, we combined this technique with a kind of microscopy that takes advantage of the fact that when you expand something, you fill it with water and it becomes transparent. That means you can take a series of 2D pictures at different depths, blazingly fast, to create a 3D scan. This microscope is called the lattice light-sheet microscope.

How do these brain analysing technologies connect with each other?
These are all part of a 50-year plan that I have long been thinking about, to actually solve the brain. The idea is, we use expansion microscopy to make a map of the brain, use voltage imaging to see activity throughout the brain and use the optogenetic tools to perturb the brain activity.

Then, we combine these three data sets to make biologically accurate models of how brains compute. I hope we can understand what thoughts and feelings really are.

Could you use this to investigate the nature of consciousness?
We still don't have a way of measuring consciousness. We are just at the beginning of this multi-decade quest. I'd argue that if you could understand the processes in the brain that occur during or before the generation of a conscious state, that would at least tell us something about how consciousness arises.

Does it tell you what consciousness is?
I think we would have to do the science and understand what the process of generating consciousness is like before declaring victory. Even if we could measure the neural correlates, that is not the same as quantifying an actual conscious experience.

Can the expansion technique be used to investigate neurological disorders too?
Yes. In collaboration with Eric Betzig's group at the Howard Hughes Medical Institute – who invented the lattice light-sheet microscope – we mapped out how myelin varies in different cell types. Myelin is really important for nerve conduction and it goes wrong in diseases like multiple sclerosis.

> "Almost as a joke, we started thinking maybe we should blow the brain up"

We were also able to look at the shapes of all the cells of a single type, dopamine-releasing cells, in a fly's brain. Dopamine is important for learning and memory, reward and addiction, and also in Parkinson's disease.

Another group has used expansion microscopy to look at human epilepsy brain specimens, removed during surgery. They were expanded to analyse the changes in the brain that occur in people who have seizures. We are also investigating other brain disorders like Alzheimer's and brain cancer. Such images might yield better treatments by helping us understand the disease better.

JUSTIN KNIGHT

Ed Boyden is a neuroscientist at the Massachusetts Institute of Technology who pioneered optogenetics, a technique to switch brain cells on and off using light

What else can you use it for apart from blowing up brains?
Another application is in early disease diagnosis. Early detection is hard to do for many diseases, because the changes are so subtle. But by expanding a biopsy, our hope is to bring the invisible early signs of disease into the large-scale visible realm. In 2017, we showed this could be helpful with breast cancer and kidney disease. I co-founded a company to explore this area.

Have you made any progress in treating disease yet?
Li-Huei Tsai at the Massachusetts Institute of Technology has been using our optogenetic tools to discover patterns of brain activity that can help clean up Alzheimer's-like symptoms in a mouse. If you can stimulate brainwaves at the right frequency, it boosts the activity of cells that clear away toxic proteins such as amyloid.

Her team, with our help, went on to find that if you play lights and sounds in the right pattern, you could stimulate these same brainwaves, which actually halt the degenerative process of Alzheimer's, in mice.

Li-Huei and I co-founded a company that is running human trials of lights and sounds delivered at this frequency, to see if we can treat Alzheimer's disease. It is too early to reach any conclusions yet, but our hope is that we can do something that is very efficacious, but also very accessible. What could be cheaper than a movie? ▮

Clare Wilson is a reporter at *New Scientist*. Follow her on Twitter @ClareWilsonMed

The undiscovered dinosaurs

Could the golden age of dinosaur discovery still be ahead of us? **Riley Black** digs around

GETTY IMAGES PLUS

THE name "tyrannosaur" conjures up images of towering predators with enormous heads and ridiculously small arms. But *Moros intrepidus* wasn't like that. This 96-million-year-old tyrannosaur was the size of a deer, a lanky pipsqueak of a predator.

It is far from the only dinosaur to strut onto the stage this year – 31 new species have been named so far. There's *Bajadasaurus pronuspinax*, discovered in Patagonia, which hit the headlines for the forward-facing spines jutting from its neck, and little *Ambopteryx longibrachium,* unearthed in China, which confirmed that some feathery dinosaurs flapped around using bat-like wings.

These add to a tally of more than a thousand species of dinosaur known to have roamed Earth in the Triassic, Jurassic and Cretaceous periods – everything from tiny omnivores no bigger than a pigeon to long-necked dinosaurs that stretched over 30 metres long.

"The pace of dinosaur discovery is so fast these days, one could label it frantic," says palaeontologist Lindsay Zanno of North Carolina State University. And it shows no sign of letting up just yet. It seems we are entering the golden era of dinosaur discovery.

The very first dinosaurs evolved about 245 million years ago, during the early part of the Triassic period (see diagram, page 46). Most stayed small until a mass extinction of their reptilian rivals cleared the way for dinosaur domination during the Jurassic period. This is when dinosaur evolution kicked into high gear, and the trend continued through the Cretaceous until another mass extinction wiped out most dinosaurs 66 million years ago. Birds are the only dinosaurs that survived, which is why researchers often distinguish between avian and non-avian dinosaurs.

Humans have long endeavoured to understand dinosaurs. At Flag Point in southern Utah, for example, pictographs created nearly a thousand years ago by Native Americans unmistakably document Jurassic dinosaur tracks found nearby. Dinosaurs as we know them today got their name in 1842, when English anatomist Richard Owen first used the word in a report on Britain's fossil reptiles, dinosaur meaning "terrible lizard". At the time, only three had been uncovered: the carnivorous *Megalosaurus*, the herbivorous *Iguanodon* and the armoured *Hylaeosaurus*.

The Great Bone Rush of the late 19th century quickly increased that number, with classics such as *Triceratops* and *Ceratosaurus* bringing the ancient reptiles fame. Museums raced to source showstopper specimens to draw in the crowds. Yet while these might have impressed the public, dinosaurs weren't especially inspiring to those who studied fossils and the evolution of life on Earth. For much of the 20th century, many palaeontologists viewed these creatures as anomalies that deserved their extinction for being too big and strange to survive. It took a renaissance in the late 20th century – a total rethink of dinosaurs as hot-blooded, successful animals – to spark the ongoing search for ever more of them.

> **"Dinosaurs were viewed as anomalies that deserved their extinction"**

Explorations in Asia, South America and elsewhere soon delivered a stunning array of new species. Entire groups never seen before were introduced, such as the bulldog-snouted, carnivorous abelisaurs from the southern hemisphere and the famous feathered-dinosaurs from China. "When I compare what we knew about dinosaurs when I was a student and what we know now, I'm astounded," says palaeontologist Catherine Forster of George Washington University.

Finding every single species of dinosaur that ever lived is an impossibility because the fossil record is an incomplete transcript of life on Earth. The best we have are small snapshots from places where sediment was deposited, such as floodplains and dune-covered deserts, that were then thrust to the surface where palaeontologists can find them. We will know little, if anything, about those dinosaurs that lived in environments that eroded away, like mountains.

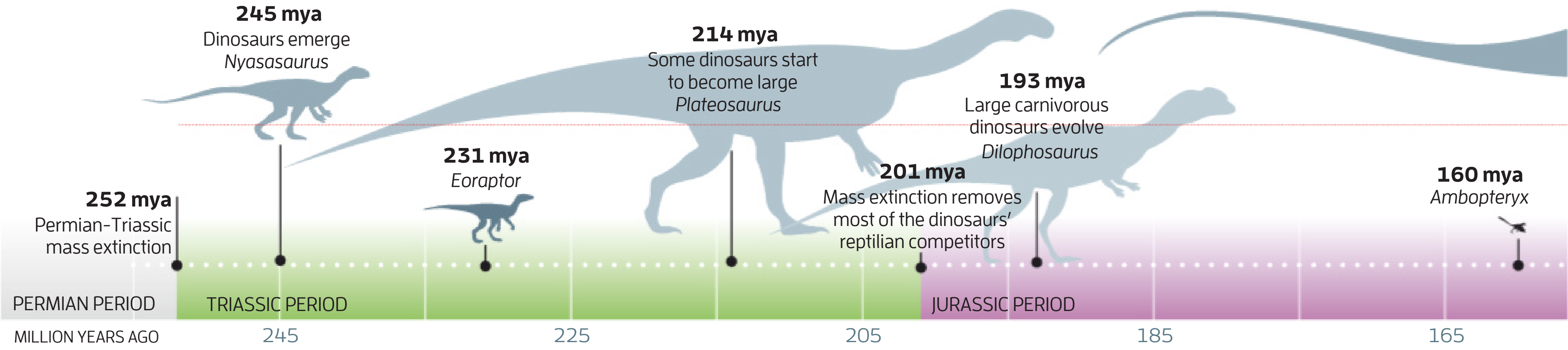
But there are ways to predict what may be out there. One is to look at what has already been found in a group to estimate what undiscovered species might still be awaiting discovery. This is where discoveries like the tyrannosaur *M. intrepidus* – whose name is derived from the Greek term for impending doom – help. The earliest members of the tyrannosaur family show up in North America's fossil record about 150 million years ago. Yet they are then virtually absent until about the 80-million-year mark, when they re-emerge as giant, big-headed, tiny-armed apex predators. "Tyrannosaurs just pop up in North America during the last 15 million years of the Cretaceous as large-bodied predators sitting atop the food chain," says Zanno.

M. intrepidus changes that story. Its bones were first spotted jutting out of a site in Utah back in 2013 ,and it was described as a new species by Zanno and her colleagues earlier this year. At 96 million years old, it sits right in that gap and indicates that tyrannosaurs in the region must have had their growth spurt sometime between that 96 and 80-million-year time slice. "*Moros* opens a window on what the ecology of tyrannosaurs was like before they rose to power," she says.

M. intrepidus does something else, too. There are now two fossil gaps on either side of the dinosaur – its ancestors and its later relatives – that are waiting to be filled. Each ›

The reign of the dinosaurs

Dinsosaurs first emerged a quarter of the way through the Triassic period. By the beginning of the Jurassic, they were the dominant land animals and it stayed that way until an asteroid hit Earth at the end of the Cretaceous. Some of these dinosaurs are depicted here, at the time when they first appear in the fossil record



new find bring up questions about how that discovery connects to others, and where to look to fill the remaining gaps.

Another way to predict the missing dinosaurs is to turn to maths. In biology, organisms are categorised by their species and the genus that the species belongs to, and researchers have devised models to estimate the numbers of dinosaur genera and species that once existed. In 2006, for example, statistician Steve Wang of Swarthmore College, Pennsylvania, and Peter Dodson, a palaeontologist at the University of Pennsylvania, estimated that there were about 1850 genera of non-avian dinosaurs that palaeontologists had some hope of discovering, based on published records of dinosaur discoveries and a mathematical formula that links observed data to unseen types. At that time, about 500 had been named, indicating that more than 70 per cent were yet to be found.

More recently, in 2016, ecologists Jostein Starrfelt and Lee Hsiang Liow at the University of Oslo, Norway, accounted for both the incompleteness of the fossil record and biases in how the fossil record is studied – for example, by the different research interests of academics – to come up with an estimate of 1536 discoverable dinosaur genera. At that time, 974 had been identified, meaning that 37 per cent were yet to be found.

This illustrates just how much progress has been made in uncovering lost dinosaurs in recent years. Even so, the dinosaur record may be richer than the predictions say. "I think the estimate of total richness for the dinosauria we made is an underestimate," says Starrfelt. Not only are there likely to be updates to the models used to estimate dinosaur diversity, but new discoveries in familiar formations will alter dinosaur counts and bump up the numbers of those yet to be found.

In 2010, for example, Richard Butler at the University of Birmingham, UK, and his colleagues described one of the smallest dinosaurs yet found. Named *Fruitadens haagarorum*, this omnivorous biped with prominent teeth was found in the Morrison Formation, a rich and well-studied source of dinosaur fossils dating from near the end of the Jurassic. And last month another small dinosaur, an early raptor named *Hesperornithoides miessleri* was described from the same formation.

It is the search for small dinosaurs like these that is filling in our understanding of even well-examined places. "New research has shown that small dinosaurs are strongly underrepresented in the fossil record because their delicate bones are more susceptible to destruction by scavengers and the elements before they can become fossils," says David

JORGE GONZALEZ

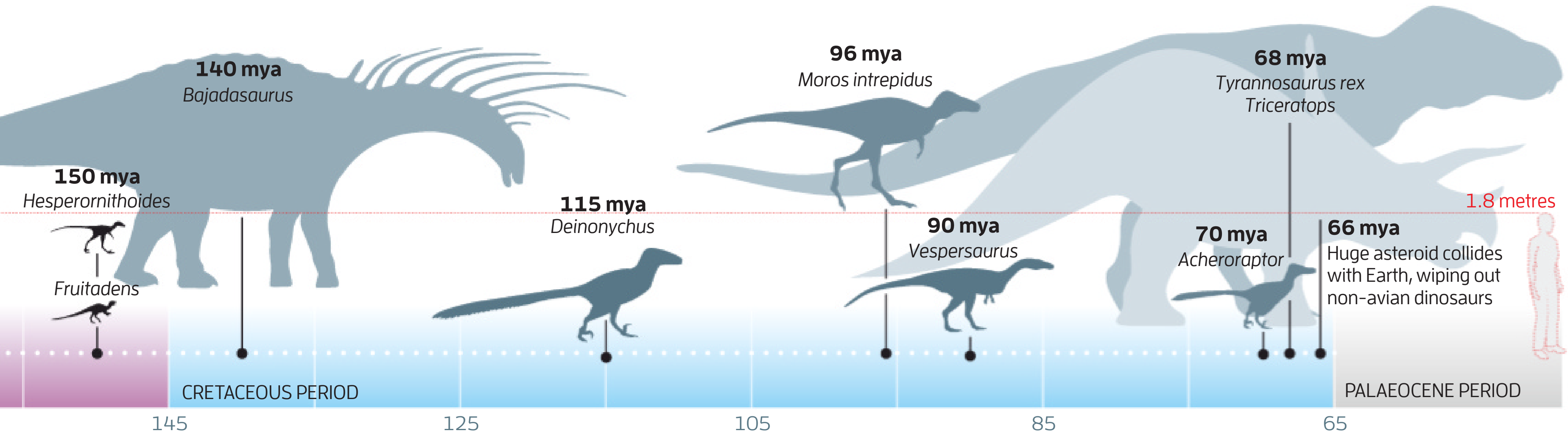
Diminutive *Moros intrepidus* wasn't such a tyrannical tyrannosaur

GOING OUT WITH A BANG OR A WHIMPER?

One of the worst days in the history of the planet transpired 66 million years ago. An enormous asteroid struck what is now the Yucatan peninsula in Central America, sparking a mass extinction. It eradicated every non-avian dinosaur, 93 per cent of all mammals, as well as many other forms of life. But were the likes of *Tyrannosaurus* and *Triceratops* going strong until the end, or had they already begun to fade away?

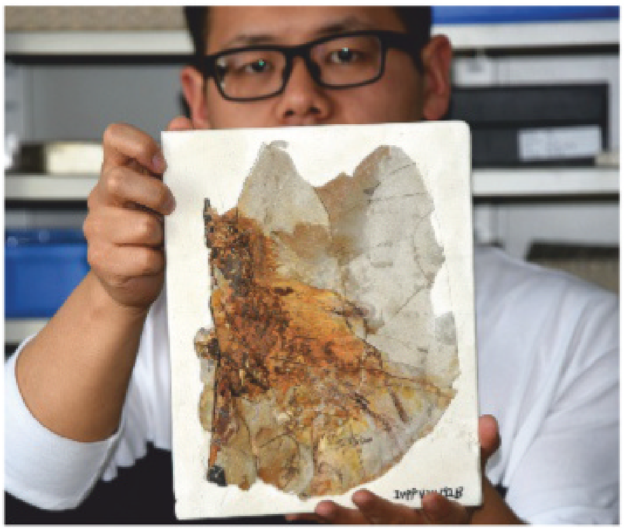
At first glance, it appears that the dinosaurs might have been waning. Diversity counts seem to show that there were more species 75 million years ago compared with when the asteroid struck, with especially high numbers recorded in western North America. But it now seems that apparent boom is partly down to a fluke of preservation. At that time, a shallow inland sea created a broad swath of floodplain environments where dinosaur bodies were more likely to get buried quickly and so be preserved. By 66 million years ago, this had largely drained away, leaving fewer places for fossilisation to occur.

When this bias is taken into account, it seems that dinosaurs were not only doing fine just before the asteroid hit, but that there may be many more to discover from the last days of the Cretaceous. Many of the places where we know they lived and where they might be preserved are relatively unexplored, in particular the eastern side of the US. The story of the last days of the dinosaurs isn't yet complete.



Evans at the University of Toronto, Canada. But they are out there. "Over the past two decades, many of the new dinosaur species being recognised from classic localities like Dinosaur Provincial Park in Alberta and in the Hell Creek Formation of the western US are on the small end of the dinosaur size range, below the size of an average person," he says.

"We are just scratching the surface in terms of dinosaur diversity," says Evans. "The potential to fill in our knowledge of dinosaur diversity on the small end of their size range is huge." This includes unusual forms of dinosaurs as well as species similar to those we have already found. In June this year, for instance, Max Langer at the University of São Paulo in Brazil, and his colleagues, described an unusual dinosaur they named *Vespersaurus paranaensis* in the Cretaceous rock of southern Brazil. The dinosaur belonged to an enigmatic group called noasaurs, and stands out by having feet that balanced the dinosaur's weight on a single toe of each foot, which seem to match strange tracks found nearby. But similar tracks are also seen in older Jurassic rocks – indicating that another one-toed dinosaur is still awaiting discovery in those older strata.


SUN ZIFA/SIPA USA/PA IMAGES

When alive, this dinosaur glided on bat-like wings

So where can we look to find all these missing species? There is still a great deal of dinosaur-bearing rock that has yet to be searched even once, much less dug into for detail. "Some of the future hotspots for dinosaur palaeontology are in south-eastern and central Asia, much of Africa, and some northern countries of South America," says Zanno. Remote, difficult-to-work sites could yield important finds, too. "The Arctic and Antarctic have huge potential for new dinosaur discoveries," says Evans. The Cretaceous strata of Africa is also little-explored compared with that in other parts of the world, he says, and could yield important finds. That is still a lot of ground to cover.

Some time periods are hazy in the palaeontological imagination. "Targeting poorly known time periods, like the Middle Jurassic, is critical," says Forster. This was the time period during which dinosaurs truly became globally dominant and increased the range of sizes they were capable of reaching.

The novelty of these finds will undoubtedly continue to make headlines. But there is more to this than raw numbers. "Dinosaurs, or any fossils, are part of our collective past," says Forster. Finding new species is the first step in visualising and understanding evolution and extinction. As Forster says, "dinosaurs and ourselves are all part of the same ever-changing system". ▮

Riley Black, who previously wrote under the name of Brian Switek, is author of *Skeleton Keys*, and *My Beloved Brontosaurus*

THE FIRST DINOSAUR

Over the past 40 years, palaeontologists have spent a great deal of time investigating the last of the dinosaurs. It is only more recently that they have begun to get acquainted with some of the first.

From discoveries in the 1990s, such as the metre-long *Eoraptor lunensis* found in Argentina, it seemed like the earliest dinosaurs emerged about 228 million years ago in the middle of the Triassic period. But fieldwork in eastern Africa has taken the dinosaur record back even further, dramatically altering our image of what the first dinosaurs were like.

In 2013, researchers described *Nyasasaurus parringtoni* from a 245-million-year-old partial skeleton unearthed in Tanzania. The skeleton is too fragmented to tell if it is definitively one of the first dinosaurs, but along with more complete remains of related animals called silesaurs, it gives us clues about what the first ones were like.

Instead of being rapacious carnivores that tore their way onto the evolutionary scene, the earliest dinosaurs seem to have been lanky, German shepherd-sized animals that probably ate plants as well as insects. They were comparatively meek creatures that lived in a world dominated by relatives of crocodiles.

Along with many other forms of reptiles, dinosaurs sprung up in the wake of Earth's worst mass extinction 252 million years ago. But they didn't dominate from the start. Most were small and on the ecological sidelines until another mass extinction 200 million years ago removed most of their reptilian competitors.

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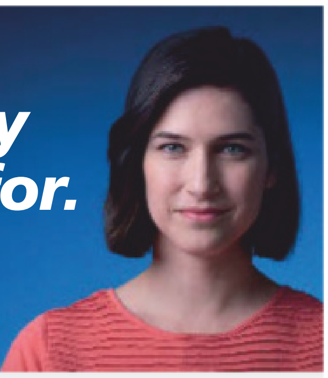

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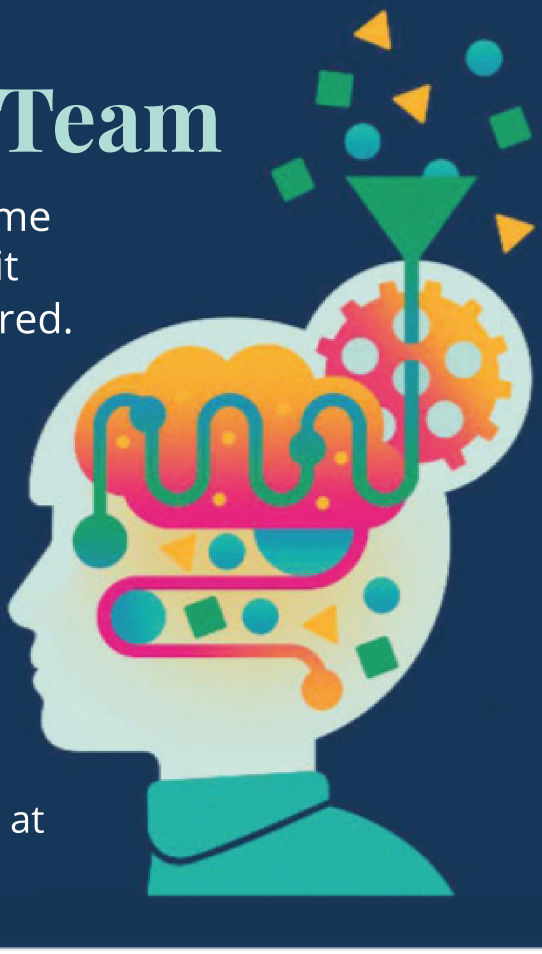

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How to be a maker 2 **Week 4**

Let garden birds tweet online

Is your garden home to birds, badgers or bears when you aren't there? Find out with **Hannah Joshua**'s tweeting wildlife camera

Hannah Joshua is a science writer and maker based in London. You can follow her on Twitter @hannahmakes

New stuff you need

Old smartphone
Phone stand

For next week

Kitchen foil
Soft sponges
Thin plastic document folder
Piezo buzzer
Electrical wire
Waterproof container

Next in the series

1 Moisture-sensing plant
2 Moisture and temperature-sensing plant
3 Plant auto-waterer
4 Tweeting wildlife cam
5 Pest scarer
Help keep rats at bay
6 BBQ thermometer
7 Rain alarm
8 Mini weather station
9 Remote controlled pest-proof bird feeder part 1
10 Remote controlled pest-proof bird feeder part 2

NOW for something completely different. Maker projects aren't just about microcontrollers and small electrical components. They are also about recycling old tech, and harnessing apps and online tools to supercharge your abilities.

This week we will pair an old smartphone with internet wizardry to make a motion-activated camera that posts pictures to social media. That will let the birds in your garden tweet as many selfies as they want.

To start, get hold of an old smartphone. All it needs is an internet connection and a camera. Clear any old photos off it – you don't want to accidentally tweet embarrassing old holiday snaps.

There are three parts to the project: take the photo, get it online and post it on social media. For step one, we can use a free motion-detection app. I am using Motion Detector Pro for Android phones, but if you have an iPhone, you can use Motion Detector Cam Free. When the app is open, it will take and save a photo every time something moves in front of the phone's camera.

Now download the Dropbox app and make an account if you haven't got one already. Dropbox is a cloud service offering 2GB of free online storage, or more for a fee. The free account is plenty for us. In the app's settings menu, find "Camera uploads". Turning this on will synchronise your phone's photos with a folder in your Dropbox account. So every time a pic is taken by the motion detector, it will get uploaded to the cloud.

DAVID STOCK FOR NEW SCIENTIST

Make online
Projects so far and a full list of kit required are at newscientist.com/maker Email: maker@newscientist.com

Now for the clever bit. There is a free app or web service called If This Then That (IFTTT) that enables you to connect different apps and accounts. It lets you make routines that have two parts, a trigger and an action. If this trigger happens, then that action gets done.

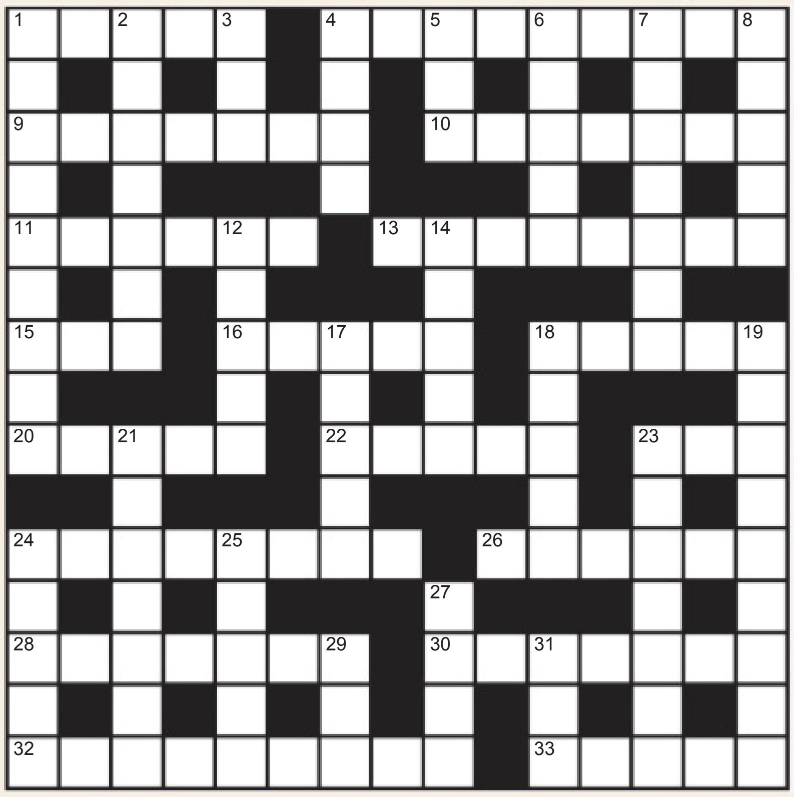
Make an account, log in to IFTTT and hit "new applet" to create your first routine. Click "+this", then search for "Dropbox" to connect that account. Follow the directions, then select the "New photo in your folder" option. Enter "Camera uploads" in the box (since this is the name of the Dropbox folder your phone photos are syncing to) and hit "create trigger".

Next, click on "+that" and search for Twitter. You will be prompted to connect your Twitter. Make a dedicated account for your garden to stop the wildlife monopolising your personal feed. Select the action called "Post a tweet with image". Enter any text you want to accompany your tweets then click "create action" and "finish". Your wildlife camera is ready.

Leave it in a window, plugged into a battery pack or charger, or stash it in a clear, weatherproof container outside.

Now your gardens are online, they can make friends. Tweet me @hannahmakes and I promise to follow every one of them. ▮

Quick crossword #37 *Set by Richard Smyth*



ACROSS

1 Immature form of a dragonfly, for example (5)
4 Type of malicious code inserted into software (5,4)
9 Portable gadget launched by Sony in 1979 (7)
10 In anatomy, the middle (7)
11 Colour between red and yellow on the visible spectrum (6)
13 See 12 Down
15 Form of H_2O (3)
16 ___ Valdez, oil tanker that struck a reef in 1989 (5)
18 Spokes (5)
20 Soft sheepskin leather (5)
22 Synthetic material (5)
23 φ (3)
24 Ceefax or ORACLE, for example (8)
26 Disconnect from power supply (6)
28 Tympanic membrane (7)
30 Deficiency in red blood cells (7)
32 MSN chat client, launched in 1999 (9)
33 Doughnut shape (5)

DOWN

1 Term for classical mechanics (9)
2 Software designed to cause harm (7)
3 Low, continuous sound (3)
4 Organ of respiration (4)
5 Precious stone (3)
6 Sequence of nucleotide triplets (5)
7 Sesame or sunflower, for example (7)
8 Lawrence ___, Nobel prizewinning physicist and X-ray crystallographer (5)
12/13 Swedish climate activist, b.2003 (5,8)
14 H (5)
17 Firm best known as a pioneer in photocopying (5)
18 Enzyme secreted by the kidneys (5)
19 Fish-derived collagen (9)
21 Gut component between the stomach and duodenum (7)
23 Macromolecule composed of many subunits (7)
24 thm (5)
25 $\sqrt{9}$ (5)
27 Two ducks? (4)
29 MB (informally) (3)
31 Insect of the family Formicidae (3)

Answers and the next cryptic crossword next week.

Quick quiz #14

1 Which area of the brain's frontal lobe, crucial for language processing, is named after a 19th-century French anatomist who studied speech impediments?

2 "Spukhafte Fernwirkung" – whose phrase, about what?

3 The red veil of St Agatha supposedly saved the city of Catania from the advancing lava of which volcano?

4 The American alligator takes its formal name from which US river?

5 Which moon of Saturn is famed for the icy geysers shooting from near its south pole?

Answers below

Cryptic Crossword #11
Answers

ACROSS 1 Antenna, **5** Catch, **8** Adieu, **9** Fanmail, **10** Extraordinary, **11** Vienna, **12** Turban, **15** Country Dances, **18** Own Goal, **19** Islet, **20** Steak, **21** Dandify
DOWN 1 Amaze, **2** Thistle, **3** Neural Network, **4** Affirm, **5** Configuration, **6** Tiara, **7** Halcyon, **11** Vacuous, **13** Bacilli, **14** Eyelid, **16** Ulnae, **17** Satay

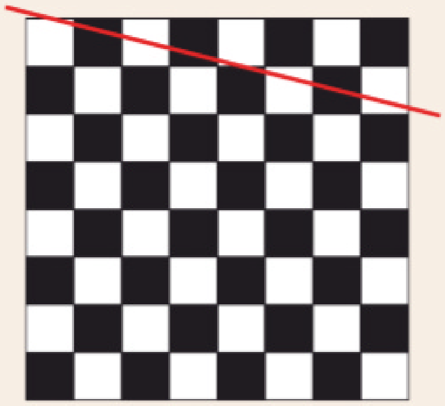
Quick quiz #14
Answers

1 Broca's area, named after Pierre Paul Broca
2 Albert Einstein's, about quantum entanglement – a phrase usually rendered into English as "spooky action at a distance"
3 Mount Etna, Sicily
4 The Mississippi – it is *Alligator mississippiensis*
5 Enceladus

Puzzle *set by Hugh Hunt*

#15 Lines through the chessboard

The red line passes through nine squares

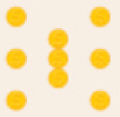


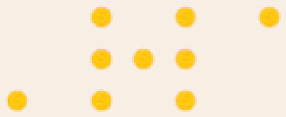
Linus is using a thin felt-tip pen and a ruler to draw straight lines on a conventional 8x8 chessboard. With eight lines, he can easily ensure that a line passes through every square on the board. For instance, he can just draw a line through the middle of each row of squares, which means each line would go through eight squares. But a line can pass through more than eight squares – for example, the one in the illustration goes through nine - so Linus wants to find a way to cut through all 64 squares with fewer than eight lines. Can you help?

Answer next week

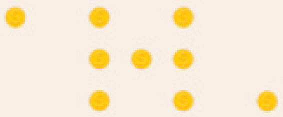
#14 The H coins problem
Solution

Add two coins to seven coins that are in an H configuration to make 10 lines of three like this:





(There is a third solution, which is just a mirror image of the second solution.)



Get in touch
Email us at
crossword@newscientist.com
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That’s methed up

In these troubled times, it can be difficult to know exactly what flavour of dystopia we are living through. There are moments when it seems like the one where a superintelligent AI takes over the world; then a heatwave strikes and it all feels closer to a *Mad Max*-style anarcho-wasteland. For a few days last week, however, it looked as though something radically different was going to devastate the human race: meth-crazed mutant crocodilians from the swamps of Tennessee.

On 15 July, CNN reported that police in the “volunteer state” had asked residents to stop flushing their drugs down the toilet during police raids, because of the risk to local wildlife. “Ducks, geese and other fowl frequent our treatment ponds and we shudder to think what one all hyped up on meth would do,” the police wrote on Facebook. Break into a breadcrumb factory, probably, or hold up park visitors at beakpoint for seeds. But the situation was set to get worse: the drugs could make it as far as Shoal Creek, the police warned, home to a population of alligators.

Sadly for those of us whose interest was piqued by this newer, scalier brand of apocalypse, the existence of “meth gators” turned out to be a humorous exaggeration. A few days after their initial announcement, the police admitted that they had been joking. The risk of becoming the victim of an alligator’s bad trip remains vanishingly small.

But that may still be preferable to the future awaiting those beside the Gulf of Mexico, where a population of American crocodiles has set up home in the grounds of a nuclear power station. Classified as a vulnerable species following decades of human persecution, the colony of crocodiles inhabiting the canals around the power plant in Turkey Point, Florida, is being closely monitored by conservationists, who are perhaps wary of the emergence of a vengeful superpowered mutant croc.

“American crocodiles have a bad reputation when they are just trying to survive,” wildlife biologist Michael Lloret told the Associated Press. “They are shy and want nothing to do with us. Humans are too big to be on their menu.” For now, Michael. For now.

Captain Instagram

If we are to face an army of irradiated super-crocs, it is only fair that the human race has its own superpowered hero to lead the charge. Thankfully, social media influencers are hard at work on their own origin stories.

Previously, Feedback noted how visitors to the “Siberian Maldives” (a photogenic pool of ethereal blue that is also a flooded coal ash dump) were risking painful skin irritations to get likes on Instagram (27 July). Now, the Spaniards are at it too, following the discovery of an equally vivid lake in Monte Neme in Galicia. Several people have now fallen ill after bathing in this tailings pond of an abandoned tungsten mine.

If there is one thing we know from comic books, it is that a dip in toxic goo is a sure-fire way to get super: just ask Daredevil or the Teenage Mutant Ninja Turtles. As far as we know, none of the Siberian or Galician swimmers has achieved the power of flight or super strength, but surely it is only a matter of time before one of them is granted something better than dermatological distress.

Money to burn

Heroes need cool kit if they are to fight crime – and mutant crocodiles – in style. Thankfully, our current dystopia provides both a challenge and a solution. Hitting the shelves imminently is the Throwflame TF-19 Wasp, a long-distance incendiary device that can be attached to a commercial drone.

The $1500 gasoline-fuelled flamethrower can dispense up to 100 seconds of fiery justice over a range of 7 metres. The Throwflame website describes the device as “designed for remote ignition of aerial and ground targets” – well, what did you expect? – and notes that it isn’t considered a weapon under US federal law. Hoo-ah!

Liana Finck *for New Scientist*

Throwflame also says its drone attachment brings “new levels of efficiency and manageability to agriculture”. Ah yes, agriculture. Repeat after us: no officer, I haven’t seen any drug-crazed alligators nearby. This? Oh, this flame-drone is just an old piece of farming equipment. Good day!

Is it a bird...?

Meanwhile, Steve Jones notes that superheroes may already walk among us. On Instagram, pop star Grimes sticks her tongue firmly in her cheek to reveal her training regimen.

“I first maintain a healthy cellular routine where I maximize the function of my mitochondria with supplements such as NAD+, Acetyl L-Carnitine, Magnesium, etc [...] From that point I spend 2-4 hours in my deprivation tank, this allows me to ‘astro-glide’ to other dimensions - past, present, and future.

“In the afternoons I do a 1-2 hour sword fighting session with my trainer, James Lew [...] I have also eliminated all blue light from my vision through an experimental surgery that removes the top film of my eyeball and replaces it with an orange ultra-flex polymer that my friend and I made in the lab this past winter as a means to cure seasonal depression.” She adds: “I go to bed with a humidifier on.”

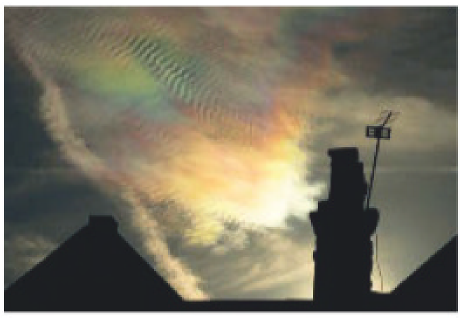
Our guess is that the Canadian warbler is mocking the over the top workout plans of fellow celebrities such as Mark Wahlberg. But just to be on the safe side, Feedback is making a spotlight that beams a maple leaf silhouette into the sky in times of crisis. ▮

Got a story for Feedback?

Send it to New Scientist, 25 Bedford Street, London WC2E 9ES or you can email us at **feedback@newscientist.com**

Special effects

I took this picture of the sky over Wimbledon, London, on 13 May at around 6 pm, two and a half hours before sunset. How are these spectacular effects created?



Bernard Burton
Wokingham, Berkshire, UK
The effect is known as irisation or iridescence and is caused by diffraction of sunlight or moonlight by very small particles. These are usually water droplets but, in theory, any particles that are sufficiently small and numerous, such as very fine volcanic ash, can create the effect.

Diffraction, or the bending of light rays by obstacles in their path such as water drops, is the same as that produced by a small aperture in a screen, according to Babinet's principle. The amount of bending varies with the wavelength, so resolution into different colours occurs in the case of visible light.

David Muir
Edinburgh, UK
The clouds that look like ripples on a sandy beach are called altocumulus undulatus.

The rainbow fringe effects have formed in a layer of thin cloud, which is probably a patch of altostratus translucidus. If a cloud's tiny water droplets or ice crystals are uniform in size, sunlight is diffracted to produce beautiful pastel colours. Each wavelength of light is dispersed by a different amount, creating the band effect.

The ribbon of cloud running roughly parallel to the slope of the first roof is a persistent condensation trail from the exhaust of an aircraft. Cloud experts sometimes call this cirrus homogenitus, a name that indicates its origin.

Mike Follows
Sutton Coldfield, West Midlands, UK
The ripples in the clouds are created by wind shear, when different layers of air move at different speeds. This causes air at the boundary to oscillate, creating ripples like those made by a breeze on the surface of a pond.

The striped pattern in the cloud is due to an oscillation called the Kelvin-Helmholtz instability. As the air from the lower layer moves upward, it cools and condenses, creating cloud. As it moves downwards again, the moisture will re-evaporate, resulting in a gap in the cloud. Pilots normally take a detour around these so-called billow clouds because they betray the presence of potentially dangerous turbulence.

Chris Daniel
Llansanffraid Glan Conwy, UK
The iridescence effect is named after Iris, the Greek goddess of rainbows. But unlike rainbows, which are due to reflection and refraction and which give ordered colour displays, iridescence is caused by diffraction.

The effect happens within 10 degrees of the sun or moon when light scatters as it passes through layers of very small and similar sized water droplets or ice crystals. The proximity of the sun to the cloud as seen by the observer can wash out the effect unless the sun is shielded from sight, as it is in this photo by a building.

If the sun is between 10 and 40 degrees away from the cloud, the effect may be due to interference similar to that seen in soap bubbles. Light is divided as it passes through the water or ice particles and recombines with a phase difference that is detectable by a change in colour or brightness.

Iridescence is just one of dozens of beautiful and intriguing effects, collectively known as photometeors or atmospheric optical phenomena.

LLEEROGERS/GETTY

Why do ginger biscuits go soft when exposed to air but cakes go hard?

This week's new questions

Hard baked **Why do crisp ginger biscuits go soft if left exposed to the air for a couple of days when other baked products, such as cakes and bread, go hard?** ***Edward Sexton****, Leeds, UK*

Still waters **When a container of liquid is rotated on its base in an upright position, the liquid inside doesn't turn with it and remains static. Why is this?** ***Stefan Badham****, Portsmouth, Hampshire, UK*

A key question

We keep the key to our holiday cottage in a four-digit key safe by the door. Because of my poor eyesight, I move only one of the digit rotors when I leave, so it is easier to open next time. Most visitors rotate all rotors on leaving. Is my behaviour riskier? (continued)

Peter Bauer
Egg Harbor City, New Jersey, US
The risk is quite high, regardless of how you lock it.

If a rotary barrel lock of this type has only one rotor scrambled, simply put tension on the lock by pulling on it. All the rotors except one will then be easy to move. Turn that one until the resistance disappears and the lock will open.

This approach usually works even if all the rotors are scrambled. Due to manufacturing variations, one rotor will carry more of the tensile load than the others and resist most when you try to turn it. Turn that one until it releases and another will take its place.

Repeat with the next most resistant rotor and so on, then the lock will be open in seconds. You may have to pull hard to sense slight differences in resistance and it may not work with very precisely machined locks, but this method has always worked for me.

My wife uses one of these locks to secure our bicycles and I never had to learn the combination. ■

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In the beginning was physics.
A-Z of Scientists
Research: what I am doing when I don't know what I am doing.
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Quantum physicist and broadcaster **Jim Al-Khalili** on oil painting, the nature of space-time and why he once wanted to play football for Leeds United

As a child, what did you want to do when you grew up?

As a young boy, I wanted to be an inventor. But by my teens, I had decided that I also wanted to be a rock star and to play for Leeds United. So yeah, not very ambitious then!

Explain what you do in one easy paragraph.

I am an explainer. As a professor of quantum physics, I conduct research into the tiniest particles that make up the world. I also spend about half of my time communicating scientific ideas to the wider public. It keeps me busy. No time to play for Leeds United.

What do you love most about what you do?

I get as much pleasure explaining complex scientific concepts as I do in finding them out for myself in my research. But probably my greatest love is writing.

Sum up your life in a one-sentence elevator pitch...

I've always been curious about the universe and have been lucky enough to pursue a career that has allowed me to find answers. But more importantly, I have a loving, happy family that I really am far more proud of than any of my scientific achievements.

What's the most exciting thing you're working on right now?

We have just written a paper on the foundations of quantum mechanics. We are trying to understand how quantum systems like atoms do what they do. Our work, I hope, will have implications in a new field of science that I am working in, called quantum biology – basically, what distinguishes life from non-life and does that have any connection with quantum physics?

Were you good at science at school?

Pretty good. I also liked art and music, though my favourite subject was definitely maths.

If you could send a message back to yourself as a kid, what would you say?

I'd say, "Believe in yourself. Listen to advice, but don't let others talk you out of pursuing your dreams."

What's the best piece of advice anyone ever gave you?

Probably what my wife, Julie, told me many years ago. We were about to get married and I felt I needed to do the responsible thing and earn a living. She told me to follow my dream and do a PhD and that we could manage. I did, and we did. And I'll always be grateful to her.

If you could have a long conversation with any scientist, living or dead, who would it be?

Oh, Albert Einstein, without a shadow of a doubt.

What's the best thing you've read or seen in the past 12 months?

Reality Is Not What it Seems and *The Order of Time*, by the cosmologist Carlo Rovelli. Translated from the original Italian, they retain a beautifully poetic charm and are full of profound ideas.

> "Space and time have no meaningful existence without gravity, even out in the emptiness of space"

Do you have an unexpected hobby, and if so, please will you tell us about it?

Oil painting. If only I had more time for it.

How useful will your skills be after the apocalypse?

Terrible. You can't defeat zombies with mathematical equations. But I'm fit and healthy and pretty resourceful, so who knows...

OK one last thing: tell us something that will blow our minds...

This is something from an appendix of a book by Einstein. We think of gravity as a force acting between objects within space-time. In fact, the gravitational field is space-time. So, just as there can be no gravity without space and time for it to act in, space and time themselves have no meaningful existence without gravity, even out in the emptiness of space. This is because the reality of space and time is inextricably linked to the existence of matter and energy within it. ▮

Jim Al-Khalili is professor of quantum physics at the University of Surrey, UK, an author and a broadcaster. His first novel, the sci-fi thriller Sunfall, is out now

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